# The American Midland Naturalist

**Devoted to Natural History, Primarily that of the Prairie States**

Founded by J. A. Nieuwland, C.S.C.

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Contents



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# The American Midland Naturalist

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VOL. 22 SEPTEMBER, 1939 NO. 2

## Plants of Crater Lake National Park

Elmer I. Applegate

Crater Lake National Park overlaps the Cascade Mountains of southern Oregon. Its area is 250.52 square miles, a tract approximately 12 by 18 miles in extent. The lake itself occupies the summit, the great caldera some 6 miles in diameter, 4000 feet deep, half full of water. Radiating from the rim of the crater are great glacier made gorges. On the east and south are Bear, Sand, Sun and Annie Creeks, emptying their waters into the Klamath River system; on the west Rogue River cuts deep into the pumice with its various branches; the low divide on the north separates the South Umpqua River on the west from the waters of the Deschutes River on the east.

The altitude ranges from about 3800 feet in the southwest corner, at the bottom of Redblanket Canyon, to the top of Mount Scott on the east, nearly 9000 feet. The rim of the crater wall ranges from about 6700 feet (some 600 feet above the water of the lake) at Kerr Notch, to a little over 8000 feet at a dozen or more points scattered about the rim. The level of the lake is a little more than 6000 feet. Covering the area are something like a dozen cones of secondary volcanic origin, including Mount Scott on the eastern margin and Wizard Island on the west side of the lake, each with its miniature crater. Union Peak, the core of a separate and older volcano, is nearly 7700 feet high and occupies the southwest quarter of the park.

At a comparatively recent date, the truncated remains was surmounted by the top of a mountain comparable to that of Mount Shasta, down whose sides glaciers ran their courses. A stupendous cataclysm reduced the mountain to its present topography. In due time the present forest and its accompanying smaller vegetation came about.

The Klamath Basin connecting with the eastern plains area introduces an element of Rocky Mountain and plains vegetation. The Klamath River gap and the Siskiyou Mountain cross range provide pathways for west coast and California plants. Some of these find lodgement on the west side of Klamath Lake, a few range into the deeper canyons of Crater Lake. On the west side other west coast and California species enter the park, the greater number by the way of the deep canyon of Redblanket Creek. On the north a large number of northern origin find their way along the Cascade Range, several reaching their southern limit at Crater Lake. A few come in from the west

from the very old formation, the Siskiyou Mountains; while a dozen or more are endemic.

The most influential factor in the distribution of plants is temperature. The temperature depends largely upon altitude. Therefore we find a grouping of plants into more or less definite belts of vegetation. Beginning in the lowest part of the Klamath Basin, at about 4000 feet above sea level, we have the Upper Sonoran Life Zone, which occupies only the valley bottoms and warm, exposed slopes. This zone extends a little above Modoc Point and higher on the precipitous fault scarp east of Klamath Lake. Some of the characteristic plants are *Juniperus occidentalis,* the only tree, reaching into the zone above, *Artemisia tridentata* (sagebrush), various species of *Chrysothamnus, Sarcobatus vermiculatus* (greasewood), *Rhus trilobata, Tetradymia canescens.* At the south entrance we have the Transition Life Zone. In this the southern species mingle with those of northern origin. It is best typified by *Pinus ponderosa* (western yellow pine). With it are *Libocedrus decurrens* (incense cedar), *Abies concolor* (white fir), *Pseudotsuga mucronata* (Douglas fir), *Pinus Lambertiana* (sugar pine), *Purshia tridentata* (bitter-brush), *Ceanothus velutinus* (snowbrush), *Arctostaphylos patula* (green-leaf manzanita). The yellow pine belt extends upward to about 5500 feet, a point nearly opposite the East Fork of Annie Creek, where *Pinus contorta Murrayana* (lodge-pole pine) becomes the dominant tree. This tree is the best indicator of the Canadian Life Zone. Included in it are *Pinus monticola* (western white pine), *Arctostaphylos nevadensis* (mat manzanita), and the overlapping *Abies magnifica shastensis* (Shasta fir) running into the zone above. This zone extends up to about Annie Spring, near 6000 feet and perhaps two miles, where we encounter the Hudsonian Life Zone. The typical tree is *Tsuga Mertensiana* (mountain hemlock), occupying the upper half or more of the whole park area, the dominant tree of the park. Mingled with it is Shasta fir, *Abies lasiocarpa* (alpine fir) and *Pinus albicaulis* (white bark pine), the latter occupies the exposed rim and the tops of cones. On the east side there is almost a pure stand on the top of Cloud Cap, reaching the summit of Mount Scott, where it is reduced to an occasional prostrate shrub. There is no timber-line, although there are several plants belonging to that area. This is known as the Arctic-Alpine Life Zone, and is above the growth of timber. Mount Pitt on the south and Mount Thielsen near to the north barely reaching that height.

It must be understood that various local factors influence the zonal distribution, such as exposure, moisture, base level and so on. For example, on the west side of the lake where there is more shade on the precipitous wall of the crater, the dominant tree is the mountain hemlock; while at the opposite side, the increased heat is reflected in the prevalence of yellow pine, white fir, green-leaf manzanita and even common sagebrush and many other Transition plants. Yellow pine trees extend up the bluff to the top and no farther. Here are the white-bark pines and the usual plants of the Hudsonian Life Zone. Down Annie Creek, for example, the lodge-pole pine and other vegetation of the Canadian Life Zone are carried down by the cold water to the

plain below the yellow pines. On the other hand the yellow pines ascend the sunny side of the upper parts of the canyon above their normal position.

The southwest corner of the park is in the bottom of the deepest canyon, that of Redblanket Creek, a drop of 5000 feet in three miles, from the top of Union Peak. This is the lowest part of the park, about 3800 feet above sea level. Here we have *Tsuga heterophylla* (western hemlock), *Taxus brevifolia* (western yew), *Cornus Nuttallii* (Nuttall's dogwood), *Castanopsis chrysophylla* (tree chinquapin), *Arbutus Menziesii* (Menzies' madrono) *Acer macrophyllum* (big-leaf maple), *Quercus Garryana Breweri, Ribes sanguineum* (flowering currant) and many other Transition plants. These are seen only by the most adventuresome hiker, as are also many plants off the beaten paths such as the deeper parts of the glaciated canyons of Annie Creek and Castle Creek.

Just under the rim on the west and southwest many springs break out, forming little meadows and bogs along their precipitous way, continuing down to more level ground. A great many of the most beautiful plants are found here. On the northwest border there is rarely a shallow pond where *Nymphaea polysepala* (wocus or Indian pond lily) finds a congenial home. On and about the dripping cliffs, 500 feet high, on the east side below Kerr Notch, in dense shade of eastern slope, grow such rare species as *Saxifraga Mertensiana, Mimulus Tilingii, Draba nivalis elongata* and *Ranunculus Eschscholtzii.* In the upper part of Sun Creek valley, coming soon after the disappearance of snow, are in great numbers the lovely *Erythronium grandiflorum pallidum* with yellow flowers, and *Claytonia lanceolata,* while a little lower down on the west slope, at Coleman Creek crossing, is *Erythronium klamathense,* a species with white flowers.

Around the rim of Crater Lake, on the brink of the crater wall, are narrow precipitous slopes, facing inward. Usually these are bordered on the upper side by *Pinus albicaulis,* often dwarfed and hedge-like; these support a group of plants of wide geographic range which are common in low arid regions and high mountain areas. Here radiation takes place more rapidly under a clear and dry atmosphere, causing a corresponding lowering of the temperature at sunset. In this respect it has been found that the arid plains and desert regions are identical with the exposed open slopes of the upper mountain areas. The usual plants common to the two regions are provided with adaptive modifications which have to do with the regulation of their heat, and the conservation of moisture, such as depauperate and depressed forms with special epidermal structures which provide for a slow rate of evaporation to keep them from drying up. They also have highly developed root systems which enables them to reach down for available soil moisture, providing at the same time for the maintenance of a foothold in the loose and shifting material in which the plants often grow. Cloud Cap furnishes the best example, possessing the greatest number of species of the group of any similar area within the park. In the Lava Beds National Monument, a hundred miles to the south, in the open Upper Sonoran Life Zone, while a few of the species are distributed over the entire area, the greater number are

found on the miniature volcanic cones. These are covered with a good depth of pumice sand with a top layer of cinders, the latter apparently serving as a mulch of moisture-conserving material, as does also the coarse pumice gravel of the Crater Lake slopes. The following species are common to both regions: *Eriogonum ovalifolium vineum, Eriogonum umbellatum, Gilia congesta, Leptodactylon pungens, Holodiscus glabrascens, Penstemon speciosus, Potentilla glandulosa, Erigeron compositus, Eriophyllum lanatum, Senecio Howellii, Hulsea nana.*

In 1827, Peter Skeen Ogden, factor of the Hudson's Bay Company, came up the Deschutes River, and over the divide and beyond. Captain John C. Fremont followed the same route in 1843 as far as the Klamath Marsh, camping there. They were in close view of the rim of Crater Lake, especially of Mount Scott. On his way north through the Cascade Mountains with the Williamson Expedition, in 1855, Dr. J. S. Newberry passed very near Crater Lake, making important botanical discoveries. But none of these saw the lake.

During the autumn of 1877, a considerable party, the largest to date, from Linkville (Klamath Falls) and Rogue River Valley, visited Crater Lake. The present writer, a small boy, was among them.

The initial botanical work, however, began in August, 1896. The Mazamas, an Oregon mountain climbing organization, held their annual encampment here, forty members being present. At this time they named the Crater Lake Mountain, Mount Mazama. At their invitation, Dr. Frederick V. Coville, Chief Botanist, and John B. Leiberg, U. S. Department of Agriculture, reached the lake on August 13, remaining a week. There were also present Dr. C. Hart Merriam, Chief of the U. S. Biological Survey and his assistants, Chief Field Naturalist Vernon Bailey and Edward A. Prebble and Cleveland Allen, Associates. Dr. Merriam was engaged in working out his Life Zone investigations. Mr. Martin W. Gorman, one of the Mazamas, and a well known Oregon botanist, furnished Dr. Coville with an excellent series of specimens collected by himself at Crater Lake. Dr. Merriam placed at his disposal a few specimens which he had collected on Llao Rock. During the week of his stay at Crater Lake, my brother and I made a trip for him across the lake, up the bluff east of the Wineglass, and on up to the summit of Mount Scott, where we spent the night amid the snow-drifts. A part of my report to Dr. Coville appeared in his account of his investigation of the Crater Lake plants, "The August Vegetation of Mount Mazama," in volume one, number two of the magazine Mazama, a record of mountaineering in the Pacific Northwest. This was the first botanical publication of Crater Lake, and contained about 175 plants.

There were also present Dr. J. S. Diller of the U. S. Geological Survey and Dr. Barton W. Evermann, Ichthyologist of the U. S. Fish Commission, and later Director of the California Academy of Sciences, Golden Gate Park, SanFrancisco. With him we returned across the lake, a stormy night, from Mount Scott.

There appeared a few days later a special forestry committee, among whom

were Gifford Pinchot, U. S. Chief Forester, Dr. Charles S. Sargent, Director of the Arnold Arboretum (Harvard Universtiy) and John Muir.

The following year Mrs. R. M. Austin of Prattville, Plumas County, California, visited the lake and did some collecting.

At that time Crater Lake was comparatively inaccessible and little known outside of southern Oregon. Three days were usually consumed from Ashland or Jacksonville on the west side over the old military road up Rogue River, completed in 1865. From Linkville on the east side, about the same time was required. The Crater Lake road, such as it was, left the military road about a mile north of Annie Spring, west of the main divide. It proceeded about two and a half miles northeasterly up the west side of the Crater Lake mountain (Mount Mazama) to the rim at the summit of the Cascade Mountains.

The seasons of 1897 and 1898, I was assistant to Dr. Coville. These two summers we were engaged in an investigation of the range question throughout the Oregon Cascade Mountains, traveling with pack train. Both years Crater Lake was visited, and a considerable number of plants collected. The first year we discovered *Botrychium pumicola* Coville.

In 1922 some "running popular notes" with 24 plant illustrations, were published in Oregon Out of Doors, Crater Lake, by the Mazamas. This was written by Mr. Albert R. Sweetser, head of the Department of Botany, State University of Oregon.

Mr. F. Lyle Wynd, graduate student of the University of Oregon, served as Ranger Naturalist for the National Park Service, in 1928, and previously. In 1936 he published "The Flora of Crater Lake National Park." This appeared in The American Midland Naturalist, published by the University of Notre Dame, Notre Dame, Indiana. It contained a list of about 420 plants of Crater Lake.

From the seasons 1934 to 1938, inclusive, I have served the National Park Service as Ranger Naturalist (botanist) at Crater Lake National Park, having besides Crater Lake, the Lava Beds National Monument, Siskiyou and Modoc Counties, California, and the Oregon Caves National Monument, Josephine County, Oregon.

To illustrate the time required to collect all the plants in a small area, I will say that I have found new ones each year. I think, however, that very few new species will be found by future botanists, although a certain amount of revision in nomenclature will be necessary.

The number of species, subspecies and varieties in the present account of the plants of Crater Lake National Park is about 570. The annotated catalogue is made up of 21 trees, 75 shrubs and 474 herbaceous plants. These are included in 60 families.

In the preparation of this paper thanks are due Dr. L. R. Abrams, Director of the Dudley Herbarium of Stanford University for helpful suggestions and words of encouragement, as well as to the following persons for assistance in the determination of critical species of plants: Dr. S. F. Blake,

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## Plants of Crater Lake National Park

### KEY TO THE FAMILIES

SPORE PLANTS *(Pteridophyta)*. Reproduction by spores, no embryo being formed.
- Fronds (leaves) usually broad, often large. Ferns and fern allies.
  - Spores borne within the tissue of a special frond. ........................OPHIOGLOSSACEAE
  - Spores borne on the surface of the fronds. ........................POLYPODIACEAE
- Fronds reduced to toothed sheaths surrounding the jointed hollowstems. Rush-like plants. ........................EQUISETACEAE

SEED PLANTS *(Spermatophyta)*. Reproduction by seeds, these containing an embryo.
- GYMNOSPERMS. Evergreen trees (in our area); stamens and ovules borne separately on the same tree (monoecious); ovules not in a closed sac (ovary), maturing into naked seeds which (except in *Taxus*) are attached to the underside of a cone-scale.
  - Fruit a woody cone or a modified cone-like berry. ........................PINACEAE
  - Fruit red, 1-seeded, drupe-like; tree or shrub with foliage like a fir. ........TAXACEAE
- ANGIOSPERMS. Ovules in a closed sac which becomes the fruit and includes the seed.
  - MONOCOTYLEDONS. Leaves mostly parallel-veined; flower-parts usually in 3's or 6's; embryo of a single cotyledon.
    - Flowers in a fleshy spadix which is enclosed in a spathe; leaves very large and broad. ........................*Lysichitum* in ARACEAE
    - Plants grass-like; leaves long, narrow.
      - Perianth none.
        - Flowers in the axils of chaffy bracts.
          - Stems hollow, jointed; leaves 2-ranked; anthers attached at the middle. ........................POACEAE
          - Stems solid; leaves 3-ranked; anthers attached at the end. ....CYPERACEAE
      - Perianth present, the parts glume-like. ........................JUNCACEAE
    - Plants not grass-like (except for the leaves of some); perianth colored (not green) and generally showy.
      - Ovary superior. ........................LILIACEAE
      - Ovary inferior
        - Flowers regular; stamens 3. ........................IRIDACEAE

Flowers irregular; stamens 1. ............................................ORCHIDACEAE

DICOTYLEDONS. Leaves net-veined; flower-parts usually in 4's or 5's.

APETALOUS SECTION. Corolla wanting; sepals present or reduced to a single bract.

Trees and shrubs.

Staminate and pistillate flowers both in catkins on separate plants (dioecious), each flower subtended by a bract. ..............................SALICACEAE

Staminate and pistillate flowers in catkins on the same plant (monoecious).

Fruit a small woody cone. ..........................................*Alnus* in BETULACEAE

Fruit a black berry in cup-like woolly bracts. ......*Garrya* in GARRYACEAE

Staminate flowers only in catkins.

Fruit a nut in a scaly cup or in a bur. ..........................................FAGACEAE

Fruit a nut in a leafy tube. ......................................*Corylus* in BETULACEAE

Flowers not in catkins.

Flowers small, greenish.

Plant parasitic on cone-bearing trees. ..............................LORANTHACEAE

Plant a tall shrub with simple, broad leaves and brownish bitter berries. ..........................................................*Rhamnus* in RHAMNACEAE

Herbs.

Ovary superior.

Pistils more than 1, distinct; stamens many. ....................RANUNCULACEAE

Pistil 1.

Ovary 1-celled.

Stipules sheathing the stems at nodes; calyx 3-6-lobed. .............. .......................................................................... POLYGONACEAE

Stipules none.

Flowers minute, greenish, in clusters; calyx 4-5-parted.

Fruit dry, 1-seeded; leaves alternate. .................................. ..........................................*Chenopodium* in CHENOPODIACEAE

Fruit a many-seeded capsule; leaves opposite. CARYOPHYLLACEAE

Flowers larger, colored, solitary or in heads surrounded by an involucre. ......................................*Eriogonum* in POLYGONACEAE

Ovary 2-celled; fruit with long double wings. ........*Acer* in ACERACEAE

Ovary 5-celled; leafless saprophytic plants with red and white striped stems. ..................................................*Allotropa* in ERICACEAE

Ovary inferior.

Leaves broad heart-shaped; flowers brownish with long segment tails. ........................................................*Asarum* in ARISTOLOCHIACEAE

CHORIPETALOUS SECTION. Calyx and corolla both present, the latter of distinct petals.

Stamens more than double the number of petals (always more than 10).

Stamens free from the calyx (hypogynous).

Pistils few to many, distinct. ..........................................RANUNCULACEAE

Pistil 1, compound.

Aquatic plant with large heart-shaped floating-leaves. .................... ..........................................................*Nymphaea* in NYMPHACEAE

Land plants.

Petals more numerous than sepals (5-16); sepals 2. ..PORTULACACEAE

Petals of the same number as the sepals (5).

Leaves alternate; stamens united. ............*Sidalcea* in MALVACEAE

Leaves opposite; stamens disposed into several bunches. ........ ..................................................*Hypericum* in HYPERICACEAE

Stamens borne on the calyx (perigynous).
Leaves opposite, simple; petals 4, white. *Philadelphus* in SAXIFRAGACEAE
Leaves alternate, with stipules. ........................................................ROSACEAE
Stamens not more than double the number of petals (10 or fewer).
Ovary superior (free from the calyx).
Pistils more than 1 and distinct from each other.
Petals and sepals of the same number as the pistils; leaves simple, fleshy. ........................................................................CRASSULACEAE
Petals and sepals not of the same number as pistils.
Leaves with stipules. ........................................................ROSACEAE
Leaves without stipules. ..............................................SAXIFRAGACEAE
Pistil only 1.
Pistil simple, as shown by the single style, stigma and ovary cell.
Flowers irregular; stamens united; fruit a pod (legume). ........ ...................................................................... LEGUMINOSAE
Flowers regular; stamens distinct.
Calyx 5-lobed; fruit 1-seeded. ..........................................ROSACEAE
Calyx of 2 sepals; fruit several-seeded; leaves fleshy. ........... .................................................................... PORTULACACEAE
Calyx of 6 sepals; anthers opening by 2 valves. ....BERBERIDACEAE
Pistil compound.
Ovary 1-celled.
Corolla irregular; the petals unlike.
Sepals 5; petals 5, the lower spurred. ..........................VIOLACEAE
Sepals 2; petals 4 (only slightly united at base). FUMARIACEAE
Corolla regular, the petals all alike.
Sepals 2; herbage fleshy. ....................................PORTULACACEAE
Sepals 4 or 5.
Leaves all opposite. ......................................CARYOPHYLLACEAE
Leaves all at base, roundish. ...............................DROSERACEAE
Ovary and usually the fruit 2-celled.
Stamens 6; herbs. ...........................................................CRUCIFERAE
Stamens in clusters; fruit winged; leaves palmately lobed. .... ...............................................................*Acer* in ACERACEAE
Stamens 4; evergreen shrub. ..............*Pachistima* in CELASTRACEAE
Ovary more than 2-celled.
Anthers opening by pores at the top. ...............................ERICACEAE
Anthers opening lengthwise.
Herbs.
Ovules and seeds numerous. ...............................SAXIFRAGACEAE
Ovules and seeds 1 to 4 in each cell; petals and stamens 5.
Leaves all entire. .................................................LINACEAE
Leaves lobed. .....................................................GERANIACEAE
Shrubs.
Stamens as many as petals and opposite them.................. ...............................................*Ceanothus* in RHAMNACEAE
Ovary inferior (adherent to the calyx).
Flowers in umbels; herbs. .................................................UMBELLIFERAE

Flowers not in umbels.
Styles 2 to 5, distinct or united below. ............................SAXIFRAGACEAE
Style 1, undivided (but sometimes with slender stigma-lobes).
Flowers scattered, in racemes or spikes; herbs. ...............ONAGRACEAE
Flowers in close rounded clusters; shrubs, herbs or trees. CORNACEAE

SYMPETALOUS SECTION. (Petals united.) Calyx and corolla both present, the latter with petals united at least at the base.
Ovary superior (free from the calyx).
Stamens free from the corolla.
Plants without green leaves. ......*Pterospora* and *Newberrya* in ERICACEAE
Plants with green leaves. ..............................*Campanula* in CAMPANULACEAE
Stamens on the corolla.
Petals only slightly united at the base.
Petals 4, in pairs; sepals 2; stamens 6. ........*Dicentra* in FUMARIACEAE
Petals 5.
Pistils 4 or 5, distinct; stamens 10. .................................CRASSULACEAE
Pistil 1.
Flowers very irregular; fruit a pod (legume). .........LEGUMINOSAE
Flowers regular; stamens many united into a tube. ....MALVACEAE
Stamens 5 or fewer.
Ovary superior.
Corolla regular.
Ovary 2, becoming a pair of pods. Plants with entire leaves and milky juice. ................................*Apocynum* in APOCYNACEAE
Ovary 1, 4-lobed, becoming 4 nutlets. ...........................BORAGINACEAE
Ovary 1, entire.
Styles 3-cleft at apex, capsule 3-celled. .................POLEMONIACEAE
Styles or stigmas 2 or 1.
Stamens opposite the lobes of the corolla. ...............PRIMULACEAE
Stamens alternate with the lobes of the corolla.
Plants perfectly glabrous. ............*Gentiana* in GENTIANACEAE
Plants more or less pubescent.
Styles 2, or 1 and 2-cleft. ........................HYDROPHYLLACEAE
Style 1, entire; fruit a berry. ...............................SOLANACEAE
Corolla irregular; stamens with anthers 4 or 2; style 1.
Ovary 4-parted, forming 4 seed-like nutlets; aromatic plants. .... ........................................................................................ MENTHACEAE
Ovary and capsule 2-celled. ....................................SCROPHULARIACEAE
Ovary and capsule 1-celled; parasites without green leaves. ...... ........................................................*Orobanche* in OROBANCHACEAE
Ovary inferior.
Stamens distinct from each other.
Leaves alternate; flowers regular; stamens 5; herbs. CAMPANULACEAE
Leaves opposite or whorled.
Stamens 1 to 3; flowers irregular, small. .................VALERIANACEAE
Stamens 4 or 5, rarely 2.
Leaves either opposite and with stipules, or whorled and without stipules. ..........................................................RUBIACEAE
Leaves opposite or perfoliate, but neither whorled nor with true stipules. ......................................................CAPRIFOLIACEAE
Stamens united into a tube around the style; flowers in a head with a calyx-like involucre. ..........................................................................COMPOSITAE

## Annotated Catalogue of Species

### 1. Ophioglossaceae. Adder's-tongue Family

#### 1. *Botrychium* Swartz. Grapefern

1. *Botrychium pumicola* Coville. Pumice Grapefern. Only about 2 inches of this little fern-like plant appear above the pumice gravel and sand of the dry, open upper slope of the crater rim. The color closely simulates that of the surroundings.—The type of this extremely rare species was collected on Llao Rock in 1896 by Coville and Applegate. In 1902 it was reported by Dr. Coville as occurring on Cloud Cap, where I found it in 1938. It was collected in 1928 in the Newberry Crater, Paulina Mountains, by Dr. L. R. Detling (226), now of the University of Oregon.

### 2. Polypodiaceae. Fern Family

Sori borne upon the veins of the frond.
 Fronds leathery, shining, evergreen, the segments with bristle-tipped teeth. ........ ....................2. *Polystichum*
 Fronds delicate, dying in winter, pinnately compound.
  Plants large, over a foot to 3 feet tall; indusium wanting. ....................3. *Athyrium*
  Plants small, usually less than a foot tall; indusium present. ....................1. *Filix*
Sori borne on the margin of the frond.
 Fronds of 2 kinds, taller spore-bearing, and shorter infertile ones. ....4. *Cryptogramma*
 Fronds all alike, or nearly so.
  Stipes greenish or light-colored, solitary; plants large, coarse, more than a foot to several feet tall. ....................5. *Pteridium*
  Stipes black or dark brown, clustered.
   Frond segments small, narrow, revolute; small plants of dry places.
    Vein ends thickened. ....................7. *Cheilanthes*
    Vein ends not enlarged. ....................8. *Pellaea*
   Frond segments larger, broad, fan-shaped; delicate plants of wet places. .... ....................6. *Adiantum*

#### 1. *Filix* Adans.

1. *Filix fragilis* (L.) Gilib. Brittle-fern. A very delicate little fern (usually not more than 6 inches high), commonly tufted in clefts of moist rocks or mossy banks; but sometimes found in more or less dry, ledgy situations. —Frequent and widely distributed over the park on both sides of the Cascade divide: Garfield trail, Union Peak trail, Castle Crest Garden, etc.

#### 2. *Polystichum* Roth.

Fronds simply pinnate, the segments serrate.
 Stipe very short. ....................1. *P. lonchitis*
 Stipes much longer. ....................2. *P. munitum*
Fronds more compound, the segments lobed or divided at the base. ....3. *P. scopulinum*

1. *Polystichum lonchitus* (L.) Roth. Holly-fern. Only sparingly abundant in our area; more often on rock ledges and cliffs, wedged in between boulders,

in middle and higher elevations.—In such places as The Watchman, Garfield trail, Slick Rock, Whitehorse Bluff and the canyon walls.

2. *Polystichum munitum* (Kaulf.) Presl. Sword-fern. Not abundant except in the heavy forest of Redblanket Creek near the southwest corner and the columnar section of Annie Creek canyon. The more common form in the park is known as *P. munitum imbricans* (D. C. Eaton) Maxon which is characterized by having more crowded segments which are more or less obliquely imbricated or overlapping.

3. *Polystichum scopulinum* (D. C. Eaton) Maxon. Shield-fern. Less frequent than the preceding, and found in dryer situations among the cliffs and ledgy crests of the upper reaches.—Rare: Garfield Peak, near the summit.

### 3. *Athyrium* Roth.

1. *Athyrium filix-femina* (L.) Roth. Lady-fern. A large extremely handsome fern with very delicate lacy fronds usually 2-3 feet tall, reaching its maximum development on wet mossy banks of deep wooded canyon streams on both slopes of the Cascade divide.—Perhaps the finest specimens are to be found along the lower Redblanket and the columnar section of Annie Creek. Near and westerly from Headquarters, around the springs of the bluff area are good specimens.

### 4. *Cryptogramma* R. Brown.

1. *Cryptogramma acrostichoides* R. Brown. Parsley-fern. Very common in the upper reaches on cliffs and crests and rock slopes.—Abundant, for example, among the boulders on the talus slope of Garfield Peak and similar situations in Castle crest Garden. Easily distinguished from all other ferns of the park by its two sorts of fronds.

### 5. *Pteridium* Scop.

1. *Pteridium aquilinum lanuginosum* (Bong.) Fernald. Brake-fern. Of frequent occurrence in the lower parts, especially in the yellow pine forest on the south side, and at intervals along the western border.

### 6. *Adiantum* L. Maidenhair

Stipes branched; segments short-stalked, elongated. ....................................1. *A. pedatum*
Stipes simple; segments long-stalked, roundish. ....................................2. *A. Jordani*

1. *Adiantum pedatum aleuticum* Rupr. Five-finger-fern. Found only where there is an abundance of moisture; thriving best on mossy stream banks in wooded canyons, especially within the spray of falls. In the park only known in the southwest corner where frequent colonies occur, extending up Redblanket Creek for more than a mile, this part of the stream descending in a series of falls and cascades. This is one of the most inaccessible areas of the park, and seldom visited.

2. *Adiantum Jordani* C. Mull. California Maidenhair. The only known

station within the park is on Whitehorse Bluff where it is very rare, growing in moist clefts of rocks, in the forest of Mountain hemlock at about 6500 feet altitude.—Like the Five-finger-fern, not known before to occur in the park.

7. *Cheilanthes* Swartz.

Fronds glabrous and naked. ........................................ 1. *C. siliquosa*
Fronds densely tomentose beneath. ........................................ 2. *C. gracillima*

1. *Cheilanthes siliquosa* Maxon. Indian Dream. Very rare within the limits of the park, except in dry rocky situations along the exposed wall of Redblanket canyon near the southwest corner.

2. *Cheilanthes gracillima* D. C. Eaton. Lace-fern. Very common from middle altitudes up to the highest points on both sides of the divide.—A small shrivelled looking fern characteristic of dry rock clefts, ledges and crests: Garfield Peak trail, Lake trail, Watchman trail, etc.

8. *Pellaea* Link.

1. *Pellaea brachyptera* (Moore) Baker. Cliff-brake. Another very rare fern in the park, except in the southwest corner. Noted only on the crest of a dry open ridge near and west of Pole Bridge, and along the exposed canyon wall of Redblanket Creek.—Plant with a large woody horizontal rhizome and a dense mass of old dried fronds and scales. The narrow segments are inclined to grow more or less in clusters spaced along the stem. Resembles *Cheilanthes siliquosa* with which it is sometimes associated.

3. Equisetaceae. Horsetail Family

1. *Equisetum* L. Horsetail

Stems simple or with whorled branches; spores borne in a terminal cone.
Cones sharp-pointed; stems perennial. ........................................ 1. *E. hyemale*
Cones blunt; stems annual. ........................................ 2. *E. arvense*

1. *Equisetum hyemale californicum* Milde. Common Horsetail or Scouring Rush. Usually found in moist places.

2. *Equisetum arvense* L. Field Horsetail. Frequent along streams, as on sandbars on Annie Creek.

4. Taxaceae. Yew Family

1. *Taxus* L.

1. *Taxus brevifolia* Nutt. Western Yew. Ours a small evergreen coniferous-looking tree or shrub with wide-spreading or drooping limbs and dark colored foliage; usually growing along streams.—Found in the southwest corner in Redblanket canyon associated with western hemlock.

5. Pinaceae. Pine Family

Leaves needle-like in sheathed bundles. ........................................ 1. *Pinus*

Leaves awl-like, not in bundles.
  Cones erect; scales deciduous. ........................................2. *Abies*
  Cones pendent, scales persistent.
    Leaves sharp-pointed; branchlets (from which leaves have fallen) rough. 3. *Picea*
    Leaves blunt or notched at apex.
      Cones with exserted 3-lobed bracts; branchlets smooth. ................4. *Pseudotsuga*
      Cones with enclosed bracts; branchlets rough with the stubs of fallen leaves.
      ........................................ 5. *Tsuga*
Leaves scale-like, minute.
  Fruit a small 6-scaled cone. ........................................6. *Libocedrus*
  Fruit a berry of united fleshy scales. ........................................7. *Juniperus*

### 1. *Pinus* L. Pine

Leaves 5 in a bundle.
  Cones about 3 inches long; scales thick, closed. ....................................3. *P. albicaulis*
  Cones about 8 inches long; scales thin, open. ....................................1. *P. monticola*
  Cones about 15 inches long; scales thin, open. ....................................2. *P. Lambertiana*
Leaves 3 in a bundle. ........................................4. *P. ponderosa*
Leaves 2 in a bundle. ........................................5. *P. contorta*

1. *Pinus monticola* Dougl. Western White Pine. Fairly common at middle elevations, scattered through the lodgepole pine forests, less frequent throughout the hemlock belt, and common on Wizard Island.—A smaller tree than the sugar pine, with thinner and grayish bark broken into small checker blocks. While not usually attaining a diameter of more than 3-4 feet, a single tree on the inner slope of the canyon of the middle fork of Annie Creek has a trunk approximately 8 feet through. This is the largest tree of any kind in the park. Some of the trees on the low lava-flow of Wizard Island have cones which are unusually small, in some instances not more than three inches in length.

2. *Pinus Lambertiana* Dougl. Sugar Pine. Only an occasional tree is to be seen well up in the yellow pine forest of Annie Creek. Farther east in the valley of Sun Creek it is more common. On the west slope it is of frequent occurrence in the canyon of Redblanket Creek in the southwest area of the park.—The largest of the pines, although with us many of our yellow pines are equal in size. The bark is thicker than that of the western white pine, of a reddish cast, and more deeply cut into irregular longitudinal furrows.

3. *Pinus albicaulis* Engelm.. Whitebark Pine. Common on the rocky crests encircling the crater rim, and of the cinder-cones including that of Wizard Island. An almost pure forest of considerable extent covers windswept Cloud Cap on the east, extending to the summit of Mt. Scott at nearly 9,000 feet, where it is often reduced to a gnarled, almost prostrate shrub. At many places there and among the crags and cliffs of the rim they cling tenaciously and assume most grotesque forms.—The thick-scaled purple cones remain closed after maturity; the clear drops of resin which cover them glistening in the sun. These cones furnish a favorite food for the raucous-voiced Clark crow who uses his strong beak to tear them apart for their seeds.

4. *Pinus ponderosa* Dougl. Western Yellow Pine. Ponderosa Pine. This tree reaches its maximum growth and greatest extension in the southern area

of the park on the Klamath side. At the south entrance is the beginning of a magnificent forest of large trees, their long bodies covered with flaky yellowish bark and crowned with yellow-green foliage. The main body of the forest lies from a little above 4,000 feet to approximately 5,000 feet altitude. In the northeasterly quarter is a smaller forest extending southeasterly from the vicinity of Timber Crater; another occurs within the eastern crater wall in the Wineglass area where it meets the white bark pine at the brink of the rim. On the Rogue River slope only small groups are found on exposed ridges and canyon walls.

5. *Pinus contorta Murrayana* (Balf.) Engelm. Lodge-pole Pine. This is the dominant tree of middle elevations, in between the yellow pine and the main hemlock forests, forming large areas of comparatively pure stands, and mingling interruptedly with other conifers up to the rim of the crater, and following down cool canyons within the park and extending considerable distances beyond its confines, on both slopes of the Cascades. Common on Wizard Island from shore to crater rim.

2. *Picea* Link. Spruce

1. *Picea Engelmannii* (Parry) Engelm. More common on the west side along streams, borders of wet meadows, swamps and bogs and within the walls of deep canyons. East of the divide it is usually confined to the streams of the deeper canyons such as Annie, Sun and Sand Creeks.—The sharpness of the leaves and the paper-like texture of the cone-scales are easy identification characters.

3. *Tsuga.* Hemlock

Cones about an inch long; lowland tree. ............................................1. *T. heterophylla*
Cones about 2 inches long; highland tree. ............................................2. *T. Mertensiana*

1. *Tsuga heterophylla* (Raf.) Sargent. Western Hemlock. Here found only at the lowest levels, entering the park at its lowest point (about 3700 feet) in the extreme southwest corner, the bottom of the canyon of Redblanket Creek. Extending up the stream in a narrow tongue for upwards of a mile, it is accompanied by a considerable number of other west coast plants not found elesewhere in the park.—The flat fern-like sprays are more delicate than those of the mountain form of hemlock.

2. *Tsuga Mertensiana* (Bong.) Sargent. Mountain Hemlock. This tree constitutes the main body of the deep and more somber forest which clothes Mt. Mazama proper, reaching up to the rim of the crater on both slopes of the divide, and to the top of Mt. Scott along with white-bark pine. The dominant tree at the camp-ground on the rim.

4. *Pseudotsuga* Carr

1. *Pseudotsuga mucronata* (Raf.) Sudworth. False Hemlock. Douglas Fir. Common at lower altitudes on the west slope, dominant in much of the lower part of the canyon of Redblanket Creek. On the east slope of rare occurrence. An occasional tree among the yellow pines along the highway

near the south entrance, and more frequent within the canyon of Annie Creek in the same area.—Readily distinguished from the true firs with which it is usually associated, by its bracted cones pendent on slender drooping branchlets, these thickly clothed with radiating leaves.

### 5. *Abies* Hill. Fir.

Cone bracts concealed.
  Cones purple, velvety. ........................................ 1. *A. lasiocarpa*
  Cones greenish, smooth. ........................................ 2. *A. concolor*
Cone bracts exserted. ........................................ 3. *A. magnifica shastensis*

1. *Abies lasiocarpa* (Hook.) Nutt. Alpine Fir. Mixed with other conifers along streams, in deep canyons, margins of swamps and wet meadows, this is a common tree in the lodge-pole pine and the hemlock forests of the west slope. On the Klamath side it is fairly abundant in the deeper parts of the canyons. Along the highway they can be seen at Pole Bridge, from where it occurs at intervals on up to the rim, and for a little distance down the inner slope of the crater just east of the Lodge. This is the only fir on the Garfield trail, except at its very base. Bordering the grassy slope at the foot of the trail, are fine examples showing the tree's habit of spreading its lower limbs flat on the ground; while near the summit, the whole tree is reduced to a prostrate form covering the slope. From government headquarters, looking southward, typical trees, with their tall, slender spires, bordering the wet meadow, stand out conspicuously.

2. *Abies concolor* Lindl. White Fir. On the Klamath side, of the conifers associated with the yellow pine, this is the most abundant; while on the Rogue River slope, this position is disputed by the Douglas tree *Pseudotsuga*. The white fir is easily distinguished from the latter by its usually longer and stiffer leaves which appear two-ranked and are disposed in broad rigid sprays. In our area the leaves are more or less emarginate or notched at the apex.

3. *Abies magnifica shastensis* Lemmon. Shasta Fir. An abundant tree throughout the upper reaches of the park. Conspicuously scattered through the lodge-pole pine belt, and more common through the hemlock forest up to the crater rim, on the inner wall of the crater and on Wizard Island. Fine trees are to be seen about government headquarters, and among the hemlocks of the rim campground.—The large cones with their highly decorative bracts are especially conspicuous perched on the upper branches. This fir has long been confused with the more northern noble fir (*A. nobilis* Lindl.). They are much alike. The leaves furnish the best distinguishing characters. That of Shasta fir is keeled on both sides, a cross-section appearing square; the leaf of noble fir is keeled or angled on one side and grooved on the other.

Although the publication of noble fir as occurring in the southern Cascades of Oregon still persists, the present writer, after more than forty years of diligent search, has never seen in the area mentioned what he recognizes as that species.

### 8. *Libocedrus* Endl.

1. *Libocedrus decurrens* Torr. Incense Cedar. A tree of the yellow pine association. A few trees occur as far up from the south entrance as the dry exposed ridges west of Pole Bridge; a few large trees stand on a similar ridge near and north of Copeland Creek crossing. Occasional along the north wall of the canyon of Redblanket Creek.

### 9. *Juniperus* Tourn.

1. *Juniperus sibirica* Burgsd. Ground Juniper. This prostrate shrub was "found by Mr. Gorman on dry rocky slopes near the Watchman," Coville in Mazama, 1896. I have been unable to find it there or elsewhere in the park.

*Thuya plicata* (giant cedar) and *Abies amabilis* (lovely fir) are two other conifers accredited to the park by various authors, including Sudworth (Forest Trees of the Pacific Slope) and Wynd (Flora of Crater Lake, 1936). To the best of my belief neither occur here. Sudworth notes that lovely fir reaches "Old Bailey Mountain (west side of Crater Lake)," which mountain is west of *Diamond* Lake and drains into North Umpqua River. The tree *is* common on Old Bailey Mountain, and reaches the summit of the Umpqua-Rogue divide but does not occur on the Rogue River side. The same is true of the giant cedar. Sudworth's statement that it is found at "Crater Lake to summit of rim at 7500 feet" is erroneous. I have noted it along all of the branches of the Umpqua up to about 4000 feet altitude, rarely that high. The noble fir *(Abies nobilis)* is another tree which comes under the same category as the two foregoing, and is treated under Shasta fir.

## 6. Poaceae. Grass Family

Spikelets pedicellate in panicles.
  Spikelets 1-flowered. ........ Tribe 1. Agrostideae
  Spikelets more than 1-flowered.
    Glumes as long as the lowest floret. ........ Tribe 2. Aveneae
    Glumes shorter than the first floret. ........ Tribe 3. Festuceae
Spikelets sessile. ........ Tribe 4. Hordeae

### Tribe 1. Agrostideae

Rachilla articulate below the glumes, these falling with the spikelet.
  Rachilla not prolonged behind the palea; panicle dense and spike-like. 1. *Alopecurus*
  Rachilla prolonged behind the palea; panicle open. ........ 2. *Cinna*
Rachilla jointed above the glumes.
  Fruit indurate, the nerves obscure; callus well developed; awn long, twisted and bent. ........ 3. *Stipa*
  Fruit thin or firm but not indurate; callus not well developed.
    Glumes longer than the lemma (equaling it in *Agrostis Thurberiana*).
      Glumes compressed-carinate, ciliate, panicle dense, cylindric. ........ 4. *Phleum*
      Glumes not compressed-carinate, not ciliate.
        Florets with hairs at base half as long as the lemma; palea present. ........ 5. *Calamagrostis*
        Florets naked at base or with short hairs. ........ 6. *Agrostis*
    Glumes not longer than the lemma, usually shorter, lemmas awned from the tip or mucronate; 3-5-nerved. ........ 7. *Muhlenbergia*

### Tribe 2. AVENEAE

Spikelets awned; florets 2 or more, all alike except the reduced upper ones.
  Awn arising from between the teeth of a bifid apex, flattened, twisted. ....8. *Danthonia*
  Awn dorsal, not flattened.
    Lemmas keeled, bidentate, awned from above the middle. ....................9. *Trisetum*
    Lemmas convex, the apex broad, erose, from below the middle. ....10. *Deschampsia*

### Tribe 3. FESTUCEAE

Lemmas 5 to many-nerved; the nerves sometimes obscure.
  Lemmas not flabellate; glumes present; inflorescence not dense and cylindric.
    Palea winged; spikelets linear, in a loose raceme. ..........................11. *Pleuropogon*
    Palea not winged; inflorescence mostly paniculate.
      Lemmas keeled on the back.
        Spikelets strongly compressed, crowded in 1-sided clusters at the ends of the stiff naked panicle branches. ..............................................12. *Dactylis*
        Spikelets not strongly compressed, not in 1-sided clusters.
          Lemmas awned from a bifid apex; spikelets large. ....................13. *Bromus*
          Lemmas awnless; spikelets small. ..................................................14. *Poa*
      Lemmas rounded on the back (slightly keeled toward the summit in *Festuca*)
        Glumes papery; lemmas firm, scarious margined; spikelets tawny or purplish, not green. .............................................................15. *Melica*
        Glumes not papery; upper florets alike.
          Nerves of lemma parallel; lemma awnless. ..................................16. *Glyceria*
          Nerves of lemma converging at the summit; lemmas awned or pointed.
            Lemmas entire, awned from the tip or pointed (minutely toothed in *Festuca Elmeri*). ...........................................................17. *Festuca*
            Lemmas awn-tipped from a bifid apex. ........................................13. *Bromus*

### Tribe 4. HORDEAE

Spikelets solitary at each joint of the rachis (occasionally 2 in *Agropyron*).
  Spikelets placed edgewise to the rachis. ...............................................18. *Lolium*
  Spikelets placed flatwise to the rachis. ...............................................19. *Agropyron*
Spikelets, at least some of them, in twos or threes at each joint of the rachis.
  Spikelets 1-flowered, not all alike, in threes, the lateral pair pedicelled. 20. *Hordium*
  Spikelets 2-6-flowered, all alike, usually in twos.
    Axis of spike continuous, not disarticulating at maturity; glumes not elongate. ..............................................................................................21. *Elymus*
    Axis of spike disarticulating at maturity; glumes setaceous and elongated. ...... ..............................................................................................22. *Sitanion*

## 1. *Alopecurus* L.

1. *Alopecurus aequalis* Sobol. Meadow Foxtail. Rather widely distributed over the area but not common.—Base of Slick Rock and west shore of the lake.

## 2. *Cinna* L. Reedgrass

1. *Cinna latifolia* (Trevir.) Griseb. A tall grass (2 or more feet high) with broad flat leaves and large drooping panicles.—Near and east of headquarters, boat landing, etc.

## 3. *Stipa* L. Needlegrass

Awn plumose.
  Sheaths pubescent. ..........................................................................1. *S. Elmeri*
  Sheaths glabrous.
    Leaves involute, mostly basal. ....................................................2. *S. occidentalis*
    Leaves flat, tardily involute, scattered. ......................................3. *S. californica*
Awn not plumose; leaves slender, involute. ........................................4. *S. Lettermani*

1. *Stipa Elmeri* Piper & Brodie. Elmer's Stipa. Reported by Wynd. Not seen.

2. *Stipa occidentalis* Thurb. Western Needlegrass. Common in open, dry woods such as the slope near and above government headquarters.—Widely distributed on both sides of the divide.

3. *Stipa californica* Merr. & Davy. California Needlegrass. Taller with longer heads than the preceding.—Common, for example, around Munson Valley, Pole Bridge and in the yellow pine woods toward the south entrance.

4. *Stipa Lettermanis* Vasey. Letterman's Needlegrass. A rather low, slender form.—Common about the Pinnacles.

### 4. *Phleum* L. Timothy

Heads cylindrical, much longer than wide. .......... *P. pratense*
Heads 2 or 3 times as long as wide. .......... *P. alpinum*

1. *Phleum pratense* L. Tame Timothy. Occasionally seen along the highways. Introduced.

2. *Phleum alpinum* L. Mountain Timothy. Common in the upper reaches, in bogs and wet places.

### 5. *Calamagrostis* Adans.

1. *Calamagrostis canadensis* (Michx.) Beauv. Bluejoint. A tall meadow grass with loose inflorescence, flat leaves and creeping rootstalks.—Frequent at Castlecrest Garden and springs near and west of headquarters, as well as along the well watered western border.

### 6. *Agrostis* L. Bentgrass

Rachilla prolonged behind the palea. .......... 1. *A. Thurberiana*
Rachilla not prolonged.
  Palea evident, 2-nerved.
    Plant tufted, a dwarfed alpine species. .......... 2. *A humilis*
    Plant with rhizomes or stolons, a taller species of lower altitudes. ....3. *A. palustris*
Plant tufted, without rhizomes.
  Panicle narrow or somewhat open, not strict; a small mountain species. 4. *A. Rossae*
  Panicle elongate; a taller plant of low altitudes. .......... 5. *A. exarata*
  Panicle very diffuse, the branches capillary. .......... 6. *A. hiemalis*
  Panicle open but not diffuse. .......... 7. *A. idahoensis*

1. *Agrostis Thurberiana* Hitchc. Thurber's Bentgrass. Wet meadow and boggy places in the upper areas.—Rather common in Munson Valley.

2. *Agrostis humilis* Vasey. Springs in the upper forests.—To be seen near and west of headquarters.

3. *Agrostis palustris* Huds. Redtop. Reported but not seen. This common cultivated grass likely to occur along the roads where there is sufficient moisture.

4. *Agrostis Rossae* Vasey. Ross's Bentgrass. A small tufted species with rather narrow panicle to be found growing in the rocks about the rim both inside and out.

5. *Agrostis exarata* Trin. Western Bentgrass. This is a larger plant than the preceding with more open inflorescence and is more likely to be found at lower altitudes.—Common in the yellow pine woods at the south entrance and along Sun Creek; also on the west slope at such places as the Copeland Creek crossing among the lodge-pole pines.

6. *Agrostis hiemalis* (Walt.) B.S.P. Ticklegrass. A species of medium size with mostly basal very narrow leaves and widely spreading and open panicle with terminal spikelets.—More frequent in meadows and along streams lower down but found around the rim in among the hemlocks in dryer situations.

7. *Agrostis idahoensis* Nash. Idaho Bentgrass. Resembling ticklegrass but with more narrow panicles and shorter branches.—Meadows of the upper slopes as at Castlecrest Garden.

### 7. *Muhlenbergia* Gmel.

1. *Muhlenbergia filiformis* (Thurb.) Rydb. Slender Muhlenbergia. The smallest grass in the park (2-6 inches high) with very narrow flat leaves.—Common in various places, including wet depressions in Munson Valley.

### 8. *Danthonia* Lam. & DC.

Panicle narrow and spikelike. ............ 1. *D. intermedia*
Panicle open, the few branches spreading in anthesis ............ 2. *D. unispicata*

1. *Danthonia intermedia* Vasey. Mountain Wild Oatgrass. A tall plant with smooth sheaths.—Rare: Whitehorse Bluff.

2. *Danthonia unispicata* Munro. Few-flowered Wild Oatgrass. A short caespitose plant with pilose sheaths and blades.—Rather rare: dry hills west of Pole Bridge.

### 9. *Trisetum* Pers.

1. *Trisetum spicatum* (L.) Richt. Spike Trisetum. A densely clumped species, 6 inches to a foot or more high; glabrous to puberulent; awn attached about one-third below the tip.

### 10. *Deschampsia* Beauv. Hairgrass

Leaves of the basal tuft filiform; panicle narrow; glumes shorter than the florets. ............ 1. *D. elongata*
Leaves thin, flat; glumes longer than the florets. ............ 2. *D. autropurpea*
Leaves, firm, narrow, becoming folded; glumes about as long as the florets. ............ 3. *D. caespitosa*

1. *Deschampsia elongata* (Hook.) Munro. Slender Hairgrass. Spikelets on short, appressed pedicels; culms densely tufted.—Castle Creek.

2. *Deschampsia autropurpurea* (Wahl.) Scheele. Mountain Hairgrass. A tall meadow and stream grass of the upper slopes, as at Castlecrest Garden.

3. *Deschampsia caespitosa* (L.) Beauv. Tufted Hairgrass. A more airy, taller species than the preceding, densely tufted.—Common, for example, in boggy places about the Copeland Creek beaver dams.

### 11. *Pleuropogon* R. Brown

1. *Pleuropogon refractus* (Gray) Benth. Nodding Pleuropogon. A very tall plant of the stream-margins of the western border; easily recognized by the nodding spikelets.

### 12. *Dactylis* L.

1. *Dactylis glomerata* L. Orchard Grass. Spikelets crowded in dense 1-sided clusters at the ends of the branches. Reported.

### 13. *Bromus* L. Bromegrass

Spikelets strongly flattened, the lemmas distinctly compressed-keeled; plant perennial or annual. ........ 1. *B. carinatus*
Spikelets not distinctly flattened and keeled.
  Panicle narrow, the branches erect. ........ 2. *B. Suksdorfii*
  Panicle open, the branches spreading or drooping.
    Lemmas pubescent along the margin and on the lower part of the back, the upper dorsal part glabrous.
      Awn 6-8 mm. long. ........ 3. *B. vulgaris*
      Awn 3-5 mm. long. ........ 4. *B. ciliatus*
    Lemmas pubescent rather evenly over the back. ........ 5. *B. Orcuttianus*

1. *Bromus carinatus* Hook. & Arn. Tall Bromegrass. Very common in the dry forested areas from the lowest yellow pine woods up to the rim of the crater. Various forms have been recognized, based largely on length of awn and degree of pubescence, including *B. marginatus* Nees. and var. *seminudus* Shear.

2. *Bromus Suksdorfii* Vasey. Suksdorf's Bromegrass. The panicle narrow and dense.—Top of Crater Peak.

3. *Bromus vulgaris* (Hook.) Shear. Common Bromegrass. Whitehorse Bluff, near and south of headquarters.

4.*Bromus ciliatus* L. Fringed Brome. Wheeler Creek.

5. *Bromus Orcuttianus*. Orcutt's Bromegrass. South entrance, Redblanket canyon.

### 14. *Poa* L. Bluegrass

Lemmas villous on the nerves.
  Creeping rhizomes present. ........ 1. *P. nervosa*
    Lemmas with a tuft of cobwebby hairs at base. ........ 2. *P. pratensis*
  Creeping rhizomes wanting. ........ 3. *P. alpina*
Lemmas not villous on the nerves. ........ 4. *P. ampla*

1. *Poa nervosa* (Hook.) Vasey. Hooker's Bluegrass. One of the rather common bunchgrasses of the yellow pine woods, as at the south entrance.

2. *Poa pratensis* L. Kentucky Bluegrass. Reported as occurring in the park, but not seen. Very commonly cultivated in the Wood River valley; doubtless introduced into the park.

3. *Poa alpina* L. Mountain Bluegrass. Widely distributed over the higher parts of the park: Union Peak, Mt. Scott, Wizard Island and at various points around the rim.

4. *Poa ampla* Merr. Merrill's Bluegrass. A tall species; panicle narrow, the branches appressed.—Common in the yellow pine woods at south entrance.

### 15. *Melica* L. Melic-grass

Lemmas long awned from a bifid apex. .......... 1. *M. aristata*
Lemmas awnless; culms bulbous at base. .......... 2. *M. subulata*

1. *Melica aristata* Thurb. Awned Melica. A tall, slender grass; lemmas 5-nerved.—Along the western boundary north of Castle Creek.

2. *Melica subulata* (Griseb.) Scribn. Alaska Onion-grass. Lemmas 7-nerved, gradually narrowed to an acuminate point.—Redblanket canyon.

### 16. *Glyceria* R. Brown. Mannagrass

Lemmas with 5 prominent nerves; low; few-flowered. .......... 1. *G. erecta*
Lemmas with 7 prominent nerves.
  Plants pale green; culms slender, either flat or folded, 2 to 6 mm. wide. 2. *G. striata*
  Plants dark green; culms 1 to 2 m. tall, rather succulent, flat, 6 to 12 mm. wide. .......... 3. *G. elata*

1. *Glyceria erecta* Hitchc. Few-flowered Mannagrass. Boggy places of high mountains. Said by Hitchcock (Manual of Grasses) to occur at Crater Lake, but not seen by me.

2. *Glyceria striata* (Lam.) Hitchc. Fowl Mannagrass. 30 to 100 cm. tall. —Copeland Creek.

3. *Glyceria elata* (Nash) Hitchc. Tall Mannagrass. Annie Creek at south entrance, Copeland Creek, end of Divide Spur, etc.

### 17. *Festuca* L. Fescue

Lemma awnless or nearly so. .......... 1. *F. veridula*
Lemmas awned.
  Awn longer than the body. .......... 2. *F. occidentalis*
  Awn shorter than the body. .......... 3. *F. idahoensis*

1. *Festuca veridula* Vasey. Mountain Bunchgrass. Culms rather loosely tufted; blades soft, scaberulous above.—Copeland Creek.

2. *Festuca occidentalis* Hook. Western Fescue. Culms slender, shining; blades filiform-involute, bright green.—South entrance.

3. *Festuca idahoensis* Elmer. Blue Bunchgrass. Culms smooth or somewhat scabrous above; blades rather stiff and firm, scabrous.—Cloud Cap, south entrance.

### 18. *Lolium* L.

1. *Lolium perenne* L. Perennial Ryegrass. Introduced from Europe.—Reported.

### 19. *Agropyron* Gaertn.

1. *Agropyron repens* (L.) Beauv. Quackgrass. A troublesome weed introduced into the United States from Europe.—Reported (Wynd).

### 20. *Hordeum* L.

1. *Hordeum nodosum* L. Meadow Barley. Along streams.—Annie Creek, Sun Creek, Copeland Creek.

### 21. *Elymus* L.

Spike slender and dense. ........................................ 1. *E. Macounii*
Spike stouter. ........................................ 2. *E. glaucus*

1. *Elymus Macounii* Vasey. Macoun's Ryegrass. Bybee meadow.

2. *Elymus glaucus* Buckl. Western Ryegrass. Fairly common at lower and middle altitudes.

### 22. *Sitanion* Raf.

Glumes, or some of them, 3-nerved. ........................................ 1. *S. Hanseni*
Glumes 2-nerved. ........................................ 2. *S. hystrix*

1. *Sitanion Hanseni* (Scribn.) J. G. Smith. Hansen's Squirrel-tail. Less common than the following.—Castlecrest Garden and Munson Valley.

2. *Sitanion hystrix* (Nutt.) J. G. Smith. Everywhere abundant from the yellow pine woods up to the rim. Especially common on open pumice fields.

## 7. Cyperaceae. Sedge Family

Achene (seed) enclosed in a sac-like perianth (perigynium). ........................................ 4. *Carex*
Achenes not enclosed, the perianth consisting of bristles.
  Bristles of the perianth very long, white silky. ........................................ 1. *Eriophorum*
  Bristles very short and inconspicuous.
    Stem with only one spikelet, not leafy. ........................................ 2. *Eleocharis*
    Stem with few or many spikelets, often leafy. ........................................ 3. *Scirpus*

### 1. *Eriophorum* L. Cotton-grass

1. *Eriophorum gracile* Koch. Slender Cotton-grass. In swamps along the western border north of Castle Creek.

### 2. *Eleocharis* R. Brown

1. *Eleocharis rostellata* Torr. Beaked Spikerush. Common throughout the park about springs, bogs, and along water courses.

### 3. *Scirpus* L.

Style branches 2; plant very tall, stout. ........................................ 1. *S. microcarpus*
Style branches 3; plant lower, slender. ........................................ 2. *S. Congdonii*

1. *Scirpus microcarpus* Presl. Rather infrequent but occurring on both sides of the divide for the most part in the lower levels, as along Annie Creek opposite the south entrance and in Bybee meadows on the western border.

2. *Scirpus Congdonii* Britton. Swamps, bogs and margins of streams on the west slope where it is sometimes 2 feet high. On the east slope the plant is reduced in size, at Pole Bridge being often not more than 6 inches high. A collection from here cited in the original publication of *S. Congdonii minor* Henderson.

### 4. *Carex* L.

Spike one.
  Stigmas three, achenes triangula.
    Perigynia strongly inflated, sessile, not becoming reflexed, pistillate scales persistent. ........................................ 1. *Inflatae*
    Perigynia not inflated; pistillate scales deciduous; perigynia stipitate, at least

the lower reflexed at maturity; perigynia dark-tinged; style jointed with achene. ....2. *Athrochlaenae*

Spikes more than one.

Stigmas two, achenes lenticular.

Lateral spikes sessile, short, the terminal one androgynous or gynaecandrous.

Perigynia not white puncticulate.

Spikes androgynous.

Perigynia with body abruptly contracted into the beak.

Spikes few (usually ten or less); perigynia green or tinged with reddish brown. ....3. *Muhlenbergianae*

Spikes numerous; perigynia yellowish. ....4. *Multiflorae*

Perigynia with body tapering into the beak. ....5. *Stenorhynchae*

Spikes gynaecandrous.

Perigynia at most thin-edged.

Perigynia spreading or ascending at maturity. ....6. *Stellulatae*

Perigynia appressed. ....7. *Deweyanae*

Perigynia narrowly to broadly wing-margined. ....8. *Ovales*

Perigynia white puncticulate. ....9. *Canescentes*

Lateral spikes elongated, peduncled or sessile; terminal spike staminate, or if rarely gynaecandrous, the lateral spikes peduncled; achenes not constricted in the middle. ....10. *Acutae*

Stigmas three; achenes triangular.

Perigynia pubescent or at least puberulent.

Pistillate spikes with from few to about 25 perigynia; bracts of non-basal pistillate spikes sheathless or nearly so. ....11. *Montanae*

Pistillate spikes very many-flowered. ....12. *Hirtae*

Perigynia glabrous.

Style jointed with achene, at length withering and deciduous.

Lowest bract strongly sheathing.

Scales greenish-or light reddish-brown-tinged; pistillate spikes slender on slender peduncles, the lower drooping. ....13. *Debiles*

Scales dark reddish-brown- to blackish-tinged. ....14. *Frigidae*

Lowest bract sheathless or very short-sheathing.

Freely long stoloniferous, not cespitose (perigynia glaucous green; pistillate spikes drooping). ....15. *Limosae*

Cespitose. ....16. *Atratae*

Style continuous with achene, indurated and persistent.

Perigynia or leaves or both pubescent. ....12. *Hirtae*

Perigynia and leaves not pubescent; perigynia coarsely ribbed. ....17. *Physocarpae*

1. *Inflatae*

Scales 3-nerved; perigynia strongly inflated. ....1. *C. Breweri*

2. *Athrochlaenae*

Short stoloniferous; staminate flowers conspicuous; perigynia early spreading or deflexed. ....2. *C. nigricans*

3. *Muhlenbergianae*

Densely cespitose; head ovoid; capitate; body of perigynium serrulate to the middle. ....3. *C. Hoodii*

4. *Multiflorae*

Perigynia 3-4.5 mm. long; pistillate scales (except lowest) acute to short-awned; beak of the perigynium shorter than body.

Ligule conspicuous, as long as wide; scales brownish-tinged; perigynia strongly nerved ventrally. ....4. *C. densa*

Ligule very short; scales reddish-brown-tinged; perigynia low-convex and strongly nerved ventrally, the body strongly serrulate above, abruptly con-

tracted into the beak. ........................................5. *C. breviligulata*

5. *Stenorhynchae*

Sheaths cross-rugulose ventrally, convex and prolonged at mouth; perigynia little spongy at base, very shallowly bidentate; stigmas short; culms not weak. ........................................6. *C. neurophora*

6. *Stellulatae*

Spikes in small (6-10 mm. long) densely capitate brownish-black head. ......7. *C. illota*
Spikes more or less widely separate, not brownish-black.
Beak of perigynium with few weak serrulations, the body broadest near the middle. ........................................8. *C. laeviculmis*
Beak of perigynium strongly serrulate, the body broadest near the base.
Culms obtusely triangular; beak of perigynium chestnut-brown-tipped. ........................................9. *C. ormantha*
Culms sharply triangular; beak of perigynium reddish-brown-tipped. Perigynia lanceolate, the beak more than half the length of body obscurely serrulate. ........................................10. *C. angustior*

7. *Deweyanae*

Perigynia shallowly bidentate, the beak about one third the length of the body. ........................................11. *C. leptopoda*

8. *Ovales*

Lower bracts leaflet-like, much exceeding head.
Beak of perigynium hyaline at orifice, obliquely cleft, bidentulate, lowest bract not appearing like a continuation of the culm. ........................12. *C. athrostachya*
Lower bracts not leaflet-like.
Sheath white-hyaline opposite blades.
Sheaths strongly prolonged upward at mouth opposite blade in a quickly ruptured very membranaceous appendage; perigynia and scales greenish. ........................................13. *C. fracta*
Upper sheaths (at least) concave or truncate at mouth opposite blades, not quickly ruptured.
Perigynia membranaceous, flattened, concavo-convex, with wide thin margins conspicuously crinkled dorsally; scales with light slender midvein. ........................................14. *C. straminiformis*
Perigynia subcoriaceous, plano-convex and thick with narrow margins not crinkled dorsally. ........................................15. *C. multicostata*
Perigynia appressed, nearly or entirely covered by scales, the beaks not consipcuous in the spikes.
Culms and head stiff, spikes approximate.
Culms 1-6 dm. high, the leaves not bunched near the base; blades 2-3 mm. wide, flat; beak of perigynium not hyaline at orifice. ..................16. *C. Tracyi*
Culms 1-3 dm. high, the leaves bunched near the base; blades 1.5-2 mm. wide, more or less involute; beak of perigynium hyaline at orifice. Perigynia oblong-ovate, rather sharply margined. ................................17. *C. phaeocephala*
Upper part of perigynia conspicuous in the spikes, not covered by the scales.
Perigynia thin, save where distended by achene.
Perigynia lance-ovate, very narrowly margined, spreading. ..........18. *C. microptera*
Perigynia ovate, strongly margined, appressed. ................................19. *C. festivella*
Perigynia plano-convex, abruptly short-beaked with conspicuous raised nerves on inner face at maturity; spikes densely capitate; perigynia conspicuously hyaline-tipped. ........................................20. *C. abrupta*
Perigynia plano-convex with thick firm walls; nerveless or inconspicuously nerved on inner face; margins of perigynia entire (or very obscurely subserrulate). ........................................21. *C. integra*
Perigynia 3.5 mm. or more in length, beaks at tip and scales brownish or blackish-tinged. ........................................22. *C. pachystachya*

Perigynia nerveless or obscurely nerved; culms slender; lower spikes more or less strongly separate; scales not conspicuously hyaline-margined. ....23. C. *Preslii*

9. *Canescentes*

Spikes androgynous; perigynia unequally bi-convex. ....24. C. *disperma*
Spikes gynaecandrous; perigynia plano-convex.
Perigynia broadest near the middle; beak short, smooth or moderately serrulate.
Plant glaucous; leaf-blades 2-4 mm. wide; spikes many-flowered; perigynia appressed-ascending, scarcely beaked, with emarginate or entire orifice. ....25. C. *canescens*
Plant not glaucous; leaf-blades 1-2.5 mm. wide; spikes fewer-flowered; perigynia loosely spreading, distinctly beaked with minutely bidentate orifice. ....26. C. *brunnescens*

10. *Montanae*

Basal spikes not developed. ....27. C. *inops*
Basal spikes present; perigynia strongly 2-keeled, othewise ribless; perigynia 3-4.5 mm. long, the beak longer, bidentate. ....28. C. *Rossii*

11. *Debiles*

Lowest bract sheathless or very short sheathing; spikes approximate; perigynia glabrous, strongly ribbed or nerved.
Perigynia ovoid-lanceolate, 4-5 mm. long, tapering into the beak, the sides strongly ribbed. ....29. C. *Whitneyi*

12. *Frigidae*

Perigynia compressed-triangular; uppermost pistillate spikes bunched, usually little exceeded by the staminate ones; blades of bracts usually less developed.
Pistillate spikes oblong; scales reddish-brown. ....30. C. *lazulina*
Pistillate spikes linear-oblong; scales dark-tinged. ....31. C. *ablata*

13. *Limosae*

Represented by one species in our area. ....32. C. *limosa*

14. *Atratae*

Terminal spike staminate or sometimes with perigynia in the middle; culms few-leaved, purple-tinged at base, the lower culm leaves much reduced; pistillate scales with prominent excurrent midvein; perigynia nerveless or nearly so on the inner face. ....33. C. *spectabilis*

15. *Acutae*

Flowering culms arising from the center of previous year's tuft of leaves and surrounded at base with dried-up leaves of previous year.
Lower sheaths of flowering culms not breaking and becoming filamentous.
Strongly stoloniferous, the culms arising one to few together, low; lowest bracts normally much shorter than inflorescence; scales with obsolete or slender midvein.
Dried first-year leaf-blades at base of fertile culms much dissected, not stiff, rigid or conspicuous, and not concealing the culms; lowest fertile culm leaves (of season's growth) not blade-bearing, the lower sheaths purplish and more or less strongly hispidulous dorsally.
Perigynia membranaceous, straw-colored or blackish-tinged; scales conspicuous.
Perigynia plano-convex or slightly bi-convex, appressed-ascending. ....34. C. *gymnoclada*

Culms taller, less stiff, in larger clumps; lowest bract usually equalling or exceeding inflorescence; scales with slender midvein or broader light-colored center.
Perigynia strongly nerved ventrally, the nerves raised.
Perigynia coriaceous, sessile or nearly so, the beak bidentate; plants strongly stoloniferous. ....35. C. *nebraskensis*

Perigynia membranaceous, more or less slender stipitate, the beak entire; plants cespitose.
Perigynia strongly stipitate, ovate.
Perigynia light-green or in age glaucous green, nerved, very minutely granular; scales long persistent. ....36. *C. Kelloggii*
Perigynia nerveless ventrally or with obscure impressed nerves.
Perigynia not turgid; scales appressed.
Sheaths colored ventrally at mouth; lower pistillate spikes subcernuous on long peduncles; scales in age whitened at tip. ....37. *C. sitchensis*
Sheaths not colored ventrally at mouth; lower piistillate spikes not nodding; scales not whitened at tip. ....38. *C. aquatilis*
Some or all of the flowering culms arising laterally and not enveloped at base by previous year's tuft of leaves; lower sheaths filamentous.
Loosely cespitose with long slender horizontal stolons; lowest bract exceeding inflorescence; foliage deep-green; lower sheaths little filamentous, hispidulous dorsally.
Perigynia suborbicular or broadly obovate. ....39. *C. eurycarpa*

### 16. *Hirtae*

Perigynia hairy, the teeth 1.5 mm. long or less.
Beak of perigynium deeply bidentate; staminate scales at most erose; foliage not pubescent; teeth of perigynium beak short.
Lowest bract strongly sheathing; fertile culms phylopodic with many leaves, the sheaths not breaking and becoming filamentous. ....40. *C. Halliana*

### 17. *Physocarpae*

Lower perigynia not reflexed; bracts moderately exceeding the spikes.
Perigynia ascending; lower sheaths more or less strongly filamentous; rootstocks short-creeping with short ascending stolons; leaves sparingly nodulose.
Perigynia 6-8 mm. long, contracted into the beak. ....41. *C. vesicaria*
Perigynia 8-10 mm. long, tapering into the beak. ....42. *C. exsiccata*
Perigynia spreading at maturity; lower sheaths not filamentous; densely cespitose, sending out long horizontal stolons; leaves strongly nodulose. ....43. *C. rostrata*

1. *Carex Breweri* Boott. Brewer's Sedge.
2. *Carex nigricans* C. A. Meyer. Blackish Sedge.
3. *Carex Hoodii* Boott. Hood's Sedge.
4. *Carex densa* Bailey. Dense Sedge.
5. *Carex breviligulata* Mackenzie. Short-liguled Sedge.
6. *Carex neurophora* Mackenzie. Alpine Nerved Sedge.
7. *Carex illota* Bailey. Small - headed Sedge.
8. *Carex laeviculmis* Meinsh. Smooth-stemmed Sedge.
9. *Carex ormantha* (Fernald) Mackenzie. Western Stellate Sedge.
10. *Carex angustior* Mackenzie. Narrower Sedge.
11. *Carex leptopoda* Mackenzie. Shorter-scaled Sedge.
12. *Carex athrostachya* Olney. Slender-beaked Sedge.
13. *Carex fracta* Mackenzie. Fragile - sheathed Sedge.
14. *Carex straminiformis* Bailey. Mount Shasta Sedge.
15. *Carex multicostata* Mackenzie. Many-ribbed Sedge.
16. *Carex Tracyi* Mackenzie. Tracy's Sedge.
17. *Carex phaeocephala* Piper. Mountain Hare Sedge.
18. *Carex microptera* Mackenzie. Small-winged Sedge.
19. *Carex festivella* Mackenzie. Mountain Meadow Sedge.
20. *Carex abrupta* Mackenzie. Abruptly Beaked Sedge.
21. *Carex integra* Mackenzie. Smooth-beaked Sedge.
22. *Carex pachystachya* Cham. Thick-headed Sedge.
23. *Carex Preslii* Steud. Presl's Sedge.
24. *Carex disperma* Dewey. Soft-leaved Sedge.
25. *Carex canescens* L. Silvery or Hoary Sedge.

26. *Carex brunnescens* (Pers.) Poir.
27. *Carex inops* Bailey. Long-stoloned Sedge.
28. *Carex Rossii* Boott. Ross's Sedge.
29. *Carex Whitneyi* Olney. Whitney's Sedge.
30. *Carex lazulina* Olney. Lazula-like
31. *Carex ablata* Bailey. American Cold-loving Sedge.
32. *Carex limosa* L. Shore Sedge.
33. *Carex spectabilis* Dewey. Showy Sedge.
34. *Carex gynoclada* Holm. Sierra Alpine
35. *Carex nebraskensis* Dewey. Nebraska Sedge.
36. *Carex Kelloggii* W. Boott. Kellogg's Sedge.
37. *Carex sitchensis* Prescott. Sitka Sedge.
38. *Carex aquatilis* Wahl. Water Sedge.
39. *Carex eurycarpa* Holm. Well-fruited Sedge.
40. *Carex Halliana* Bailey. Oregon Sedge.
41. *Carex vesicaria* L. Inflated Sedge.
42. *Carex exsiccata* Bailey. Western Inflated Sedge.
43. *Carex rostrata* Stokes. Beaked Sedge.
44. *Carex Haydeniana* Olney.

## 8. ARACEAE

### 1. *Lysichiton* Schott.

1. *Lysichiton americanum* Hulten & St. John. Skunk Cabbage. Easily recognized by its very large glabrous basal leaves and yellow spathe enclosing the fleshy spadix, after the fashion of the common Calla to which our plant is related.—A considerable colony in a bog on a small branch of National Creek at the base of Crescent Ridge. This station is near the west boundary at about 5000 feet altitude; and, as far as I know, the only occurrence in the park.

## 9. JUNCACEAE. Rush Family

Leaf-sheaths open; capsule 1- or 3-celled; many-seeded. ....... 1. *Juncus*
Leaf-sheaths closed; capsule 1-celled, 3-seeded. ....... 2. *Luzula*

### 1. *Juncus* L. Rush

The subtending leaf of the inflorescence appearing like a continuation of the stem, terete.
  Flowers few, usually 1-3 in each cluster; seeds white-tailed.
    Blade of the uppermost basal leaf-sheath well-developed; capsule acute. ....... 1. *J. Parryi*
    Blade rudimentary; capsule retuse. ....... 2. *J. Drummondii*
  Flowers usually numerous, in compound panicles; seeds not tailed.
    Stamens 3. ....... 3. *J. effusus*
    Stamens 6.
      Anthers about as long as the filaments. ....... 4. *J. filiformis*
      Anthers much longer than the filaments. ....... 5. *J. balticus*
The subtending leaf of the inflorescence not appearing like a continuation of the stem, or if so, plainly channelled inside; inflorescence appearing terminal.
Leaf-blades definitely flat. Flowers in many heads. ....... 6. *J. orthophyllus*
Leaf-blades very narrow, more or less flattened; stems slender; stamens 6. ....... 7. *J. Mertensianus*
Leaf-blades gladiate (sword-shaped); stems compressed and 2-edged; stamens 3. ....... 8. *J. ensifolius*

1. *Juncus Parryi* Engelm. Parry's Rush. Common throughout the upper levels to the highest points.—Many bunches along the beginning of the Castlecrest Garden trail.

2. *Juncus Drummondii* E. Mey. Drummond's Rush. Frequent at middle elevations on both sides of the divide: Dewey Falls, Patton creek, etc.

3. *Juncus effusus* L. Soft Rush. A tall common species (Wynd).

4. *Juncus filiformis* L. A very slender plant with an exceptionally long lower inflorescence leaf.

5. *Juncus balticus* Willd. Baltic Rush. Very tall coarse round-stemmed species (Wynd).

6. *Juncus orthophyllus* Coville. Straight-leaved Rush. Common along the upper water courses: Boundary Springs, Trapper Creek, springs west of headquarters, etc.

7. *Juncus Mertensianus* Bong. Mertens's Rush. Abundant throughout the upper levels, especially along streams and other moist places.—A black-headed, rather low species.

8. *Juncus ensifolius* Wiks. Three-stemmed Rush (Wynd's Flora).

### 2. *Luzula* DC. Woodrush

Flowers usually solitary at the ends of the branches.
  Perianth 3-3.5 mm long; leaves 10-12 mm. wide. ....................1. *L. glabrata*
  Perianth 1.5-2.5 mm. long; leaves 8-10 mm. wide.
    Pedicels drooping; leaves slightly hairy at base. ....................2. *L. parviflora*
    Pedicels spreading; leaves glabrous. ....................3. *L. divaricata*
Flowers crowded in spikes or dense clusters. ....................4. *L. campestris*

1. *Luzula glabrata* Hoppe. Smooth Woodrush. The characteristic herbaceous covering of the hemlock forest floor, and occurring in less abundance under white bark pines at the highest altitudes.—One of the noteworthy and most abundant plants to be seen about headquarters and at the rim campground.

2. *Luzula parviflora* Desv. Small-flowered Woodrush. Scattered along streams, about springs and other moist places throughout the lower levels and up into the hemlock forest areas.

3. *Luzula divaricata* S. Wats. Forked Woodrush. Not common in the park.—East slope of Mt. Scott.

4. *Luzula campestris* L. Common Woodrush. Frequent along watercourses, about springs and in meadows.—Munson Valley, Copeland Creek.

### 10. Liliaceae. Lily Family

Fruit a capsule.
  Styles 3 and distinct.
    Leaves equitant (straddling), sedge-like; flowers in 3's borne in terminal clusters; stem naked. ....................1. *Tofieldia*
    Leaves not equitant; flowers in large panicles; stem very leafy, tall and corn-like. ....................2. *Veratrum*
  Style 1.
    Stems from a tunicated bulb or corm.
      Flowers with bracts.
        Flowers in racemes, blue. ....................3. *Camassia*
        Flowers in umbels.
          Perianth segments distinct or nearly so, anthers versatile. ....................4. *Allium*

Perianth segments united below; stamens with anthers 6 or 3; anthers basifixed or versatile. ....5. *Brodiaea*
Flowers without bracts; leaves 1 or 2, basal or apparently so; anthers basifixed.
Perianth segments unlike, the inner petal-like, hairy inside; leaf narrow. ....6. *Calochortus*
Perianth segments all petal-like, glabrous; leaves broad. ....7. *Erythronium*
Stems from a scaly bulb.
Perianth (in ours) campanulate; anthers attached at base or below the middle; style 3-cleft. ....8. *Fritillaria*
Perianth funnelform; anthers versatile; style entire. ....9. *Lilium*
Fruit a berry (except Trillium).
Plants with leafy stems; stamens 6.
Stems branching; flowers few, drooping.
Flowers axillary; filaments short, flattened. ....10. *Streptopus*
Flowers terminal; filaments thread-like. ....11. *Disporum*
Stem simple; flowers many. ....12. *Smilacina*
Plants with only 2 or 3 leaves.
Leaves basal, usually 2 or 3, parallel-veined. ....13. *Clintonia*
Leaves 3 in a whorl at summit of stem, netted-veined. ....14. *Trillium*

### 1. *Tofieldia* Huds.

1. *Tofieldia occidentalis* S. Wats. Western Tofieldia. Bog-asphodel. An abundant plant, especially about springs and bogs on both slopes from middle to highest elevations.—With its clumps of small white flowers and later reddish capsules, it is a conspicuous and attractive plant in Castlecrest Garden and about the hillside springs near and west of headquarters. Also abundant in the beaverdam bogs on Copeland Creek.

### 2. *Veratrum* L.

1. *Veratrum viride* Ait. Corn-lily. False Hellebore. A very common and conspicuous plant found at most altitudes where it is not too dry. To be noted in many places along the highways. Frequently to be seen in moister soil near streams and borders of meadows, the tall stalks clothed with large clasping leaves, and terminating in large panicles of greenish-white flowers, reminding one of corn-fields.—Fine specimens occur on the slope below the rim campground, about headquarters, etc.

### 3. *Camassia* Lindl. Camas

Perianth segments irregularly disposed, one directed downward, the other ranging upward, usually twisting separately after flowering. ....1. *C. quamash*
Perianth segments regularly disposed like the spokes of a wheel, and all twisting together over the capsule later. ....2. *C. Leichtlinii*

1. *Camassia quamash* (Pursh) Greene. Common Camas. Reported by Wynd but although the abundant and common species of the Klamath Basin, I have not been able to find it within the park area. Perhaps confused with the next. One of the most important food plants of the northwest Indians. In the Klamath region great quantities of the bulbs were dug. These were barbecued in pits.

2. *Camassia Leichtlinii* (Baker) S. Wats. Leichtlin's Camas. Found in swamps only on the western border north of Castle Creek: Bybee meadows,

and meadows about 2 miles north of Copeland Creek.—A taller species than the preceding, and rarely found in southern Oregon on the east side of the Cascade range. Always blue in the park, but white and blue in separate colonies throughout the valleys of the Umpqua and Willamette rivers. Much used by Indians in early days.

### 4. *Allium* L. Onion

Plant tall with rootstock and elongated bulb. ............................................. 1. *A. validum*
Plant low without rootstock; bulb globose. ............................................. 2. *A. campanulatum*

1. *Allium validum* Watson. Swamp Onion. Common in marshy places, bogs and wet stream margins: widely distributed at upper elevations.—Frequently 2 feet high. To be seen about the hillside springs near and west of headquarters.

2. *Allium campanulatum* Watson. Sierra Onion. Rare in our area. Usually little over 6 inches high. Specimens collected on the hillside southwest of headquarters by Roy Walker, but without bulbs. It has never been seen since.

### 5. *Brodiaea* Smith

Flowers white; anthers 6; wet places. ............................................. 1. *B. hyacinthina*
Flowers purple; anthers 3; dry situations. ............................................. 2. *B. pulchella*

1. *Brodiaea hyacinthina* (Lindl.) Baker. White Brodiaea. Rare in the southwest section: moist swales, on the brink of the north wall of the canyon of Redblanket Creek near the west border.

2. *Brodiaea pulchella* (Salisb.) Greene. Ookow. Collected only on the dry north slope of Redblanket canyon where it occurs in thickets of Brewer oak.

### 6. *Calochortus* Pursh

1. *Calochortus elegans* Pursh. Cat's-ear. Only occasionally found toward the western border as on Copeland Creek and in the area southwest of Union Peak.—This is not only one of the smallest of the many species now known, but is the first species known, the type being collected on the Clearwater River in Idaho by Lewis on the famous Lewis & Clark expedition.

### 7. *Erythronium* L. Lamb's-tongue

Flowers yellow; style 3-cleft or lobed. ............................................. 1. *E. grandiflorum*
Flowers white; style 3-toothed or entire. ............................................. 2. *E. klamathense*

1. *Erythronium grandiflorum pallidum* St. John. Yellow Lamb's-tongue. One of the very earliest to flower in the hemlock belt. The center of abundance is in Sun Creek Valley, where with the appearance of the first spots of bare ground in late spring or early summer, these beautiful golden-yellow lilies begin to spring up like tulips. With the disappearance of the snow, they are seen in abundance from the rim to the road in the vicinity of Vidae Falls. On rock ledges just west of headquarters is a small colony. On the west slope on the headwaters of Redblanket Creek they are plentiful.

2. *Erythronium klamathense* Applegate. Klamath Lamb's-tongue. This white species is found only on the west slope and at a little lower level than

the yellow one. The only known station within the park is among the lodgepole pines on the upper branches of Copeland Creek. At the flowering time, this area can only be reached by hiking over several miles of snow, either from the rim road at the Watchman or from the Medford road. For the more enthusiastic plant lover it is well worth the effort.

### 8. *Fritillaria* L.

1. *Fritillaria atropurpurea* Nutt. Purple Fritillary. A characteristic plant of the yellow pine forest, and consequently more common on the east slope. West of the divide occurring on open exposed ridges, as in the vicinity of Copeland Creek crossing, and the north wall of Redblanket canyon.

### 9. *Lilium* L.

Flowers white, streaked with purple. ........................................1. *L. washingtonianum*
Flowers orange-yellow, spotted with purple. ........................................2. *L. pardilinum*

1. *Lilium washingtonianum* Kell. Washington Lily. Not often seen in the park. On a steep brushy slope east of the road about a mile north of Copeland Creek, at about 5600 feet, is a considerable colony. This can be seen from the road, some with stems several feet high supporting many flowers. In thickets of east slope of Round Top. The most beautiful and fragrant of all our western lilies.

2. *Lilium pardilinum* Kell. Tiger Lily. Even less common than the preceding. Thus far only detected along Redblanket Creek. At the monument marking the southwest corner of the park, where a small branch dashes down the precipitous canyon wall, are many fine specimens, some of them reaching a height of 5 or 6 feet.

### 10. *Streptopus* Michx. Twisted-stalk

Stems branched; pedicels geniculate. ........................................1. *S. amplexifolius*
Stems simple; pedicels not geniculate. ........................................2. *S. curvipes*

1. *Streptopus amplexifolius* (L.) DC. Common along watercourses, especially in the deep canyons.—Often several feet high and much branched. The berries white eventually turning red.

2. *Streptopus curvipes* Vail. A much smaller, simple-stemmed plant of rare occurrence. Collected by Coville and Leiberg at Pole Bridge Creek in 1896. Collected by myself on Castle Creek at the west entrance.

### 11. *Disporum* Salisb.

1. *Disporum oregana* (S. Wats.) Benth. Fairy-bells. Less common than *Streptopus* which it resembles. Easily known by its terminal inflorescence.—Occasional along lower Annie Creek, and on Redblanket Creek toward the southwest corner.

### 12. *Smilacina* Desf.

Flowers in a panicle. ........................................1. *S. amplexicaulis*
Flowers in a simple raceme.
  Leaves dull green, usually folded. ........................................2. *S. stellata*
  Leaves bright green, commonly flat. ........................................3. *S. sessilifolia*

1. *Smilacina amplexicaulis glaber* Macbride. Common at all levels throughout the area.—At south entrance along Annie Creek, about 2 feet high, gradually diminishing in height until the highest points are reached, where it becomes depauperate among the rocks.

2. *Smilacina stellata* (L.) Desf. Less common, growing in dryer and more open situations.—Infrequent in Pinnacles Valley toward the east entrance.

3. *Smilacina sessilifolia* Nutt. Wooded streams in lower and middle elevations, as along Annie, Sun and Bybee Creeks; western border.

### 13. *Clintonia* Raf.

1. *Clintonia uniflora* (Schultz) Kunth. A low plant with a slender scape of pure white lily-like flowers; leaves 2-3, commonly 2, broad.

### 14. *Trillium* L. Wakerobin

1. *Trillium ovatum* Pursh. Western Wakerobin. Flowers white, changing to rose.—Along the western border: below the end of Divide Spur; in the canyon of Redblanket Creek.

## 11. Iridaceae. Iris Family

Flowers large, parts unlike; stems terete. ....1. *Iris*
Flowers small, parts alike; stems 2-edged. ....2. *Sisyrinchium*

### 1. *Iris* L. Flag

1. *Iris chrysophylla* Howell. Flowers cream-colored, more or less streaked with purple; the tube long and slender.—Infrequent: lodge-pole pine woods near and north of Bybee Creek meadows; yellow pines west of south entrance.

### 2. *Sisyrinchium* L.

Flowers blue. ....1. *S. idahoense*
Flowers yellow. ....2. *S. californicum*

1. *Sisyrinchium idahoense* Bick. Plentiful on the west slope in meadows and bogs: Copeland Creek, etc.

2. *Sisyrinchium californicum* (Ker.) Dryand. Golden-eyed Grass. Rare: meadows of Bybee Creek.

## 12. Orchidaceae. Orchid Family

Plants with ordinary green foliage.
  Perianth with spur. ....1. *Habenaria*
  Perianth spurless.
    Flowers in a spike.
      Spike dense; leaves solid green. ....2. *Spiranthes*
      Spike more slender; leaves striped. ....3. Peramium
    Flowers in a raceme; leaves 2 near the middle of the stem. ....4. Listera
Plants without green herbage.
  Plant pure white throughout. ....5. *Cephalanthera*
  Plant reddish-brown, rarely yellow. ....6. *Corallorrhiza*

### 1. *Habenaria* Willd.

Stem leafy at the base, withering later; commonly in dry places. ....1. *H. unalaschensis*
Stem leafy, not withering.

Flowers greenish, sometimes more or less greenish-purple. .... ....................2. *H. stricta*
Flowers white. ..........................................................................................3. *H. dilatata*

1. *Habenaria unalaschensis* (Spreng.) S. Wats. *(Piperia)*. Dryland Habenaria. Common in the yellow pine woods on the south, and in Redblanket canyon in the southwest quarter.

2. *Habenaria stricta* Lindl. Green Bog Orchid. The spur very short and thick; the greenish flowers tending to turn purplish.—Very abundant from middle to upper elevations, in streams and bogs: Castlecrest Garden and the springs and little bogs west of headquarters, are accessible places where they can be found; along with the next species, the white one.

3. *Habenaria dilatata* Hook. White Bog Orchid. Flowers pure white; the spur long and slender.—More abundant, and nearly always found with the preceding.

A taller plant to be found in the yellow pine woods and elsewhere in the lower parts, and known as the species *leucostachys* seems best to be treated as a large form of *H. dilatata.*

2. *Spiranthes* Rich

1. *Spiranthes Romanzoffiana* C. & S. Twisted-stalk. Stems not usually more than 6 inches high; flowers white, in a close twisted spike.

1. *Peramium decipiens* (Hook.) Piper. Rattlesnake Plantain. The flowers resemble those of *Spiranthes;* leaves a basal cluster marked with white.—Infrequent, commonly in the hemlock forest, sometimes growing in clefts of rocks, as on the lake trail.

4. *Listera* R. Brown

1. *Listera carina* Piper. Twayblade. Plants often under 6 inches high, growing mostly in moist woods and on stream banks: Boundary springs; Divide Spur; north slope of Wizard Island.

5. *Cephalanthera* Rich

1. *Cephalanthera Austinae* (Gray) Heller. Phantom Orchid. Common in the fir forest on the north wall of Redblanket canyon, near the southwest corner of the park. Not observed elsewhere. The snow-white plants from 6-8 inches to more than a foot high.

Sepals and petals 1-nerved, often small. ..............................................1. *C. Corallorrhiza*
Sepals and petals 3-nerved; spur prominent.
  Lip 3-lobed, spotted; spur adnate its whole length. ................................2. *C. maculata*
  Lip entire, not spotted; spur free below the middle. ..........................3. *C. Mertensiana*

6. *Corallorrhiza* R. Brown

1. *Corallorrhiza Corallorrhiza* (L.) Karst. Early Coralroot. Thus far seen only in Redblanket canyon, southwest corner.

2. *Corallorrhiza maculata* Raf. Spotted Coral root. Heavy forests; not common except in certain restricted areas: Redblanket canyon; Union Peak.

3. *Corallorrhiza Mertensiana* Bong. Mertens's Coralroot. About the same range and habits as the preceding: Vidae Falls.

## 13. SALICACEAE. Willow Family

Catkin bracts entire; stamens 1-several; stigmas short. ..........1. *Salix*
Catkin bracts fimbriate; stamens numerous; stigmas elongate. ..........2. *Populus*

### 1. *Salix* L. Willow

Bud scales yellow; styles very short.
  Leaves lanceolate, glabrous above. ..........1. *S. lasiandra*
  Leaves linear, densely pilose. ..........2. *S. Hindsiana*
Bud scales brownish to nearly black.
  Capsule glabrous; leaves glabrous, lanceolate, thick, firm. ..........3. *S. pseudocordata*
  Capsules hairy.
Styles distinct.
  Leaves more or less glabrate at maturity, lanceolate or broader; stamens 2. ..........4. *S. Lemmonii*
  Leaves densely hairy (at least beneath) at maturity.
    Leaves tomentose on both sides.
      Catkins leafy-pedunculate. ..........5. *S. Eastwoodae*
      Catkins subsessile. ..........6. *S. orestera*
    Leaves with a dense silvery pubescence on the lower side; stamen 1. ..........7. *S. sitchensis*
    Leaves with a dense opaque pubescence. ..........8. *S. Coulteri*
Styles obsolete or very short; commonly in dry places. ..........9. *S. Scouleriana*

1. *Salix lasiandra Abramsii* Ball. Abrams's Willow. Tall, sometimes a tree, as on Annie Creek at south entrance.—At lower levels.

2. *Salix Hindsiana* Benth. Valley Willow. Very rare in our area; seen only along the west shore of the lake. Common along Rogue River below Prospect.

3. *Salix pseudocordata* (Anderss.) Rydb. Firm-leaf Willow. Low, growing in dense thickets in wet meadows and bogs. At Boundary Spring the boggy opening is covered with this willow, associated with swamp huckleberry. Found along streams toward the west boundary, on Sand Creek on the east side and elsewhere.

4. *Salix Lemmonii* Bebb. Lemmon's willow. Occurring on both sides along streams, in meadows and bogs, as for example above the beaver dams of Copeland Creek and on Annie Creek.

5. *Salix Eastwoodae* Cockerell. Eastwood's Willow. This and the next are characteristic of the hemlock zone where they form thickets along the watercourses, and about meadows, as at headquarters, Castlecrest Garden and Munson Valley.

6. *Salix orestera* Schneider. Sierra Willow. More common than the latter with which it is easily confused. It is usually less pubescent and the aments subsessile.

7. *Salix sitchensis* Sanson. Sitka Willow. Not very abundant. Llao's Hallway.

8. *Salix Coulteri* And. Coulter's Willow. On the west lava flow of Wizard Island, near the shore, are a few clumps that stand out conspicuously, the silvery pubescence of the leaves being very noticeable.

9. *Salix Scouleriana* Barratt. Scouler's Willow. Scattered through the dry yellow pine woods and on exposed ridges.

### 2. *Populus* L. Poplar

Stamens 40 to 80; leaves longer than broad. .......... 1. *P. trichocarpa*
Stamens 6 to 12; leaves round-ovate. .......... 2. *P. tremuloides*

1. *Populus trichocarpa* Torr. & Gray. Black Cottonwood. Tree commonly 25 to 125 feet high; stigmas 3, dilated and deeply lobed.—West shore of lake small trees; large trees at south entrance.

2. *Populus tremuloides* Michx. Quaking Aspen. Graceful tree, 10 to 60 feet high or higher; stigmas 2, very thick below.—Small trees along the highway toward the south entrance; larger ones along Annie Creek, Sun Creek, etc. Large groves in the upper part of Wood River valley.

## 14. BETULACEAE

Fruit a nut enclosed in a tubular involucre; staminate flowers solitary in the axils of the catkin scales. .......... 1. *Corylus*
Fruit a small winged nutlet under the cone-like catkin; staminate catkins longer. .......... 2. *Alnus*

### 1. *Corylus* L.

1. *Corylus californica* (A. DC.) Rose. Hazel. Found only at the following stations: lower part of Redblanaket canyon, south slope of Crescent ridge and the lower section of Annie Creek canyon.

### 2. *Alnus* Hill. Alder

Leaves firm, dull-green; flowers earlier than the leaves. .......... 1. *A. tenuifolia*
Leaves thinner, bright shining-green; flowers appearing with the leaves. .......... 2. *A. sinuata*

1. *Alnus tenuifolia* Nutt. Dull-leaved Alder. The dominant species along streams in the lower levels. Tree on Annie Creek at south entrance.

2. *Alnus sinuata* (Regel) Rydb. Green-leaved Alder. Abundant in wet places both on the outer slopes and within the crater.

## 15. FAGACEAE. Oak Family

Fruit an acorn; staminate catkins pendent. .......... 1. *Quercus*
Fruit a spiny bur; staminate catkins erect. .......... 2. *Castanopsis*

### 1. *Quercus* L. Oak

1. *Quercus Garryana Breweri* (Engelm.) Jepson. Scrub White-oak. Brewer's Oak. Dry openings in the fir forest along the north wall of Redblanket canyon, extending in thickets from the west boundary a mile or more to the east. The typical as well as the scrub form finds its way through the Klamath gap and lodges on the west side of Klamath Lake; and the small form is isolated on the north canyon slope of Stukel Mountain on Lost River. This appears to be the easternmost station of the species.

### 2. *Castanopsis* Spach. Chinquapin

A tree with pointed leaves. .......... 1. *C. chrysophylla*
A shrub with obtuse leaves. .......... 2. *C. sempervirens*

1. *Castanopsis chrysophylla* (Dougl.) A. DC. Tree Chinquapin. Found only in the lower part of Redblanket canyon near the southwest corner of the park.

2. *Castanopsis sempervirens* (Kell.) Dudley. Sierra Chinquapin. In the yellow pine woods on the south and on exposed, open situations up to the rim on both sides of the Cascade divide. There is a small colony on the top of Union Peak.

### 16. Loranthaceae. Mistletoe Family

#### 1. *Arceuthobium* Marsch-Bieb.

Staminate flowers terminal. .......... 1. *A. americanum*
Staminate flowers axillary. .......... 2. *A. camplopodium*

1. *Arceuthobium americanum* Nutt. Pine Mistletoe. Found on lodge-pole pine on Wheeler Creek and on white-bark pine on Wizard Island.

2. *Arceuthobium campylopodium* Engelm. Collected by Gill on white-bark pine.

### 17. Aristolochiaceae

#### 1. *Asarum* L.

1. *Asarum caudatum* Lindl. Wild Ginger. Abundant in the damp forest at the southwest corner monument in the canyon of Redblanket Creek, from which point it extends up the stream for perhaps a mile; otherwise not known in our area.—Low plant with large heart-shaped leaves; flowers brownish with long-tailed segments, lying flat on the ground.

### 18. Polygonaceae. Buckwheat Family

Flowers borne in a tubular or turbinate involucre; stipules wanting; sepals 6. .......... 1. *Eriogonum*
Flowers not involucrate; stipules sheath-like.
  Leaves reniform; sepals 4. .......... 2. *Oxyria*
  Leaves not reniform; sepals 6.
    Sepals unequal, the inner becoming much larger; stigmas tufted. .......... 3. *Rumex*
    Sepals equal; stigma capitate. .......... 4. *Polygonum*

#### 1. *Eriogonum* Michx.

Calyx attenuated and stipe-like at the base.
  Calyx pubescent on the outer surface. .......... 1. *E. pyrolaefolium*
  Calyx glabrous on the outer surface.
    Involucre merely toothed at the apex, the teeth short and erect; styles very short and erect. .......... 2. *E. marifolium*
    Involucre lobed, the lobes oblong or ovate-oblong, usually reflexed; styles long and recurved. .......... 3. *E. umbellatum*
Calyx not stipe-like at base.
  Involucre never congested in heads; plants pilose; leaves linear, revolute. .......... 4. *E. spergulinum*
  Involucre congested in heads.
  Calyx lobes dissimilar, the outer much broader and cordate at base; inflorescence a single terminal head. .......... 5. *E. ovalifolium*
  Calyx lobes similar.
    Leaves spreading, oblong-ovate, obtuse, in basal rosettes. .......... 6. *E. nudum*
    Leaves erect, ovate-lanceolate. .......... 7. *E. elatum*

1. *Eriogonum pyrolaefolium coryphaeum* Torr. & Gray. Leaves densely tomentose on the under side, green above; flowers tinged with rose, in dense umbels.—Open situations in the upper areas up to the highest points, including the summit of Mt. Scott. Characteristic of and very common on the open pumice flats and slopes.

2. *Eriogonum marifolium* Torr. & Gray. Dioecious Eriogonum. Forming much branched, low mats; leaves glabrous and green above, oval, 2-4 inches in length, the petiole half as long. With us the flowers are dioecious. Pistillate flowers lemon-yellow, close, on scape-like stems, 1 to 4 inches tall; styles very stubby, appearing as three dots, contrasting strongly with the long, recurved ones of *E. umbellatum* with which it is occasionally associated. Staminate flowers larger, darker yellow and with a red stripe on the outside sepals; very loose, on stems 8-14 inches tall.—Very abundant in lodge-pole pine forests, less common in areas of scattered hemlocks and white-bark pines.

3. *Eriogonum umbellatum* Torr. Sulphur-flower. The erect stems are more or less woody at base; the rays of the umbel with a whorl of large leaf-like bracts, becoming reflexed.—Most abundant and best developed in openings in the yellow pine woods, especially at the southern border; less common on the exposed rocky ridges up to the rim. On the Fort Klamath highway, just south of the park, on open, gravelly flats, there are many exceptionally attractive, large clumps of this species.

4. *Eriogonum spergulinum* A. Gray. Spurry Eriogonum. Repeatedly branched above, more or less glandular; leaves almost filiform; involucre solitary with minute pinkish flowers.—Plentiful at the Pinnacles and in the yellow pine woods at the south entrance.

5. *Eriogonum ovalifolium vineum* (Small) Jepson. This form is densely matted with short stems, bearing close heads of red flowers.—In our area confined to the highest, most exposed slopes, as the top of Llao Rock and the rim at the Wineglass and Cloud Cap.

6. *Eriogonum nudum deductum* Jepson. Stems scape-like, branched above, with white flowers and basal leaves.—Infrequent at widely separated places: along the road at headquarters, the Wineglass and west shore of the lake.

7. *Eriogonum elatum* Dougl. Tall Eriogonum. In our area the leaves are often definitely cordate; a foot tall or higher; woody horizontal root; felty undersurface of leaf and large umbels of rose-tinted flowers.

### 2. *Oxyria* Hill

1. *Oxyria digyna* (L.) Hill. Mountain Sorrel. On the high slopes and crests; frequent among large loose boulders at the bottom of the Garfield Peak talus slope.—A rather fleshy plant with a panicle of reddish flowers and kidney-shaped basal leaves.

### 3. *Rumex* L.

Plant small, slender, unisexual. ............ 1. *R. Acetosella*
Plant large, coarse; flowers with both stamens and pistils. ............ 2. *R. crispus*

1. *Rumex Acetosella* L. Sheep Sorrel. A common introduced plant scattered along roads and about camping places. One of the first plants to be brought into the park.

*Rumex crispus* L. Curly Dock. Erect stems more than a foot high, with large leaves and dense cluster of flowers, reddish in fruit.—Infrequent in moist places.

### 4. *Polygonum* L. Knotweed

Leaves broad or broadish.
  Flowers many in a dense head-like raceme. ........................................ 1. *P. bistortoides*
  Flowers few in axillary clusters. ........................................ 2. *P. Newberryi*
Leaves narrow.
  Shrub, prostrate. ........................................ 3. *P. shastense*
  Annuals.
    Flowers in axillary clusters; leaves ovate to elliptic; plant 2-4 inches high. ........................................ 4. *P. minimum*
    Flowers in rather dense terminal bracteate spikes. ........................................ 5. *P. Kelloggii*
    Flowers in loose elongated spikes.
      Flowers deflexed, green with white margin. ........................................ 6. *P. Douglasii*
      Flowers erect, white with green line. ........................................ 7. *P. spergulariaeforme*

1. *Polygonum bistortoides* Pursh. Bistort. Stems 1-2 feet high; leaves mostly basal, those above bract-like.—Very common from middle altitudes upward, in wet meadows, along streams and in bogs on both sides of the divide.

2. *Polygonum Newberryi* Small. Newberry's Knotweed. Herbage dull green, somewhat fleshy and scurfy; stems in clumps, more or less spreading; leaves about 2 inches long and nearly as broad.—A most characteristic and abundant plant of the upper open pumice fields. Later in the season the whole plant turns bright red adding much to its attractiveness.

First collected by Dr. J. S. Newberry, Cascade expedition, 1855.

3. *Polygonum shastense* Brewer. Shasta Knotweed. A small shrub forming mats with broad silvery stipules and white or pinkish flowers, 2 or 3 in the axils.—Frequent on the upper pumice slopes and crests: Llao Rock; Union Peak; Mt. Scott; flat just below the Lodge.

4. *Polygonum minimum* Wats. Small Knotweed. Stem several from the base, 3-6 inches long; flowers greenish-white.—Southeast slope of Round Top; Bybee Creek meadows.

5. *Polygonum Kelloggii* Greene. Kellogg's Knotweed. Usually 2 or 3 inches high, sometimes less than an inch.—Occasionally in meadows, early in the season in open ledgy slopes: Munson Valley; near and west of Pole Bridge.

6. *Polygonum Douglasii* Greene. Douglas's Knotweed. Stem slender, 6-15 inches high, erect, somewhat strictly branched; leaves oblong to lanceolate.—Widely distributed except in the higher areas: Copeland Creek; Godfrey Glen; headquarters.

*Polygonum Douglasii latifolium* Greene is a robust form having wider leaves.—Common in the edge of Bybee Creek meadow.

7. *Polygonum spergulariaeforme* Meisn. Glabrous throughout; stems slender, angular, dark red, erect, 3-8 inches high; flowers more or less congested above, increasingly interrupted below.—Dry, rocky exposed situations, in openings in thickets of scrub oak and other brush, near the southwest corner of the park.

## 19. CHENOPODIACEAE. Saltbush Family

### 1. *Chenopodium* L.

1. *Chenopodium album* L. Common White Pigweed. An introduced well-known weed found along roads, campgrounds, etc.—Headquarters.

## 20. PORTULACEAE. Purslane Family

Capsule 2-3 valved; sepals 2.
  Style 1; stigmas 2; sepals plane, more or less scarious. ............ 1. *Spraguea*
  Style 3-branched; sepals more or less concave.
    Roots not fleshy. ............ 2. *Montia*
    Root a globose corm. ............ 3. *Claytonia*
Capsule circumscissile. ............ 4. *Lewisia*

### 1. *Spraguea* Torr.

1. *Spraguea umbellata* Torr. Pussypaws. Low matted plant. Commonly and widely distributed, mostly in dry open spaces; reaching its maximum development from lower to middle elevations where it forms large mats. On ascending to the higher levels the plant becomes reduced in size with a branched caudex, congested foliage and inflorescence, and a greatly developed root system, running into *S. umbellata caudicifera* (Gray) Jepson.

### 2. *Montia* L. Indian Lettuce

Leaves alternate; stem scape-like. ............ 1. *M. parvifolia*
Leaves opposite.
  Stem leaves of several pairs. ............ 2. *M. Chamissoi*
  Stem leaves of one pair.
    Stem leaves united into a disk. ............ 3. *M. perfoliata*
    Stem leaves distinct. ............ 4. *M. sibirica*

1. *Montia parvifolia* (Moc.) Greene. The strict stems with small leaves running into bracts upward, surrounded by a rosette of basal leaves.—Apparently restricted to the southwest quarter, from Round Top westward along the north wall of Redblanket canyon.

2. *Montia Chamissoi* Ledeb. Toadlily. Plant from 2 to 6 inches long with small white flowers and spatulate leaves.—Rare in our limits: small depressions in Munson Valley where the plant grows in water, later the weak stems reclining in the mud and rooting at the nodes.

3. *Montia perfoliata* Donn. Indian Lettuce. Mostly in moist shady places: Lower Annie Creek.

4. *Montia sibirica* (L.) Howell. Stems usually a foot or more in height, weak; flowers white, veined with pink, on long pedicels.—Llao's Hallway; Annie Creek; Redblanket Creek; Castle Creek.

### 3. *Claytonia* Gron.

1. *Claytonia lanceolata* Pursh. Spring Beauty. An early plant of the hemlock belt, common from about Annie Spring to the rim. Especially abundant in Sun Valley above the rim road, associated with *Erythronium*.—Low glabrous plant, the scape-like stems bearing at summit a pair of lanceolate leaves and a cluster of white pink-veined flowers.

### 4. *Lewisia* Pursh

1. *Lewisia triphylla* (S. Wats.) Robinson. A dwarf plant common on rocky hillsides appearing early with such other little plants as Brewer's monkeyflower.—Stem half under ground, from a small globose tuber, the small white flower cluster subtended by two or three slender leaves.

## 21. Caryophyllaceae. Pink Family

Sepals distinct or united only at the base.
  Stipules none.
    Petals bifid or 2-divided, rarely none. ....................1. *Stellaria*
    Petals entire or merely notched, rarely none.
      Styles as many as the sepals. ....................2. *Sagina*
      Styles fewer than the sepals. ....................3. *Arenaria*
  Stipules present, scarious; petals entire. ....................4. *Spergularia*
Sepals united into a tube. ....................5. *Silene*

### 1. *Stellaria* L.

Bracts of the inflorescence small and scarious.
  Petals minute or none; flowers in umbels. ....................1. *S. umbellata*
  Petals longer than the sepals, the cymes terminal. ....................2. *S. longipes*
Bracts foliaceous; petals shorter than the sepals or none.
  Flowers cymose; leaves mostly lanceolate. ....................3. *S. borealis*
  Flowers solitary in the axils, leaves ovate. ....................4. *S. crispa*

1. *Stellaria umbellata* Turcz. Umbellate Chickweed. Stems squarish, long and weak; flowers few in more or less irregular umbels with minute petals.—Along streams: Annie Creek for example.

2. *Stellaria longipes* Goldie. Tall, more erect than the preceding.—Grassy meadows: Bybee meadow.

3. *Stellaria borealis Bongardiana* Fer. Stems spreading; leaves ovate-lanceolate.—Annie Creek below Godfrey Glen.

4. *Stellaria crispa* C. & S. Plant with long weak stems; leaves ovate and well spaced.—Annie Creek at south entrance, Redblanket canyon.

### 2. *Sagina* L. Pearlwort

1. *Sagina occidentalis* S. Wats. Western Pearlwort. Stems filiform; sepals and petals 5.—Not very common: wet rocks, Annie Creek; shoreline under Garfield Peak.

### 3. *Arenaria* L. Sandwort

Leaves subulate; plants without running rootstocks. ....................1. *A. pumicola*
Leaves linear; plants with rootstocks. ....................2. *A. macrophylla*

1. *Arenaria pumicola* Coville & Leiberg. Pumice Sandwort. Abundant throughout the upper open pumice areas; basal leaves densely tufted; plant 6 inches or more high.

2. *Arenaria macrophylla* Hook. Large-leaved Sandwort. Leaves 3 to 5 pairs; stems ascending.—Infrequent: Redblanket canyon.

### 4. *Spergularia* J. & C. Presl. Sand Spurry

1. *Spergularia rubra perennans* (Kindb.) Robinson. Dry slopes. Introduced weed.

### 5. *Silene* L. Catchfly

Flowers solitary in the upper axils or terminal, the stems leafy.
  Calyx broadly turbinate-campanulate; flowers nodding; petals 4-6 cleft. ....................1. *S. campanulata*
  Calyx broadly oblong; flowers erect; petals notched. ....................2. *S. Menziesii*
Flowers mostly scattered; stems mostly leafy at base; calyx narrowly cylindric ....................3. *S. montana*

1. *Silene campanulata* S. Wats. Bell-shaped Catchfly. Flowers white, half an inch long; the many stems form a thick crown; leaves an inch broad.—Rare in the park: Redblanket canyon in the scrub-oak area.

2. *Silene Menziesii* Hook. Menzies Catchfly. Resembling the preceding but having much smaller flowers; calyx teeth purplish.—In the white fir forest on the inner wall east of the Wineglass.

3. *Silene montana viscida* Henderson. Henderson's Catchfly. Differing from the species in being glandular instead of finely puberulent.—Lakeshore under Garfield Peak.

The type collected at Crater Lake by Lyle Wynd 2357.

## 22. NYMPHAEACEAE. Water-lily Family

### 1. *Nymphaea* L.

1. *Nymphaea polysepala* (Engelm.) Greene. Wokas. Yellow Pond-lily. So far only found in a small pond about three quarters of a mile southeast of the end of Crater Spur on the western border.

## 23. RANUNCULACEAE. Buttercup Family

Carpels numerous, 1-ovuled; fruit an achene.
  Cauline leaves three in a whorl. ....................1. *Anemone*
  Cauline leaves alternate.
    Petals wanting. ....................2. *Thalictrum*
    Petals present, white or yellow. ....................3. *Ranunculus*
Carpels few, 2-many ovuled; fruit a follicle or berry.
  Flowers irregular.
    Upper sepal spurred; petals 4. ....................4. *Delphinium*
    Upper sepal hood-like; petals 2. ....................5. *Aconitum*
  Flowers regular.
    Sepals spurred. ....................6. *Aquilegia*
    Sepals not spurred.
      Leaves simple; petals wanting. ....................7. *Caltha*
      Leaves compound; carpels becoming a cluster of red berries. ....................8. *Actaea*

### 1. *Anemone* L. Windflower

Achene with a long hairy tail. ....................1. *A. occidentalis*
Achenes not tailed.
  Achenes densely woolly; leaves dissected. ....................2. *A. Drummondii*
  Achenes not woolly.
    Involucral leaves simple and sessile. ....................3. *A. deltoidea*
    Involucral leaves lobed and petioled. ....................4. *A. quinquefolia*

1. *Anemone occidentalis* S. Watson. Western Windflower. Common in the upper levels, especially on the talus slopes. An attractive colony at the upper end of Castlecrest Garden. Conspicuous well up on the Garfield Peak trail. Flowering soon after the disappearance of the snow.

2. *Anemone Drummondii* S. Watson. Drummond's Windflower. On the open gravelly eastern slope of Union Peak is a considerable colony; rare on the Garfield Peak trail; associated with the preceding species which it resembles, but lacks the tailed achenes, and has smaller, pale blue instead of white flowers.

3. *Anemone deltoidea* Hook. Common Windflower. A plant of the western border where it is of infrequent occurrence along streams, and more common in the moist woods of lower Redblanket Creek in the southwest corner of the park.

4. *Anemone quinquefolia oregana* (Gray) Robinson. Rare on Trapper Creek and more frequent in the beaver dam area of Copeland Creek. Flowers light blue on slender stems (6-8 inches) from slender brittle rootstocks.

### 2. *Thalictrum* L. Meadow Rue

1. *Thalictrum sparsiflorum* Turcz. Few-flowered Meadow Rue. Thus far only seen on Annie Creek at the south entrance. Flowers of small greenish sepals and long conspicuous stamens; stems 2-3 feet high with leaves made up of numerous broad lobed leaflets.

### 3. *Ranunculus* L. Buttercup

Aquatic; flowers white. .......... 1. *R. aquatalis*
Terrestrial plants.
  Leaves simple, entire; achenes thickish.
    Stems rooting at the nodes. .......... 2. *R. Gormanii*
    Stems never rooting at the nodes. .......... 3. *R. Populago*
  Leaves lobed.
    Herbage glabrous; low alpine plants with broad basal leaves, subcordate. .......... 4. *R. Eschscholtzii*
    Herbage pubescent.
      Flowers large. .......... 5. *R. occidentalis*
      Flowers very small. .......... 6. *R. Bongardii*

1. *Ranunculus aquatalis capillaceus* (DC.) Benson. Water Buttercup. Shallow water on the west side of Wizard Island.

2. *Ranunculus Gormanii* Greene. Gorman's Buttercup. The most common buttercup of the park. Abundant along watercourses, and in wet meadows and bogs throughout the middle and upper areas. A small weak stemmed plant with broadly-ovate to deltoid-ovate leaves and small flowers.—Plentiful in low, wet ground in Castlecrest Garden.

The type collection made at Crater Lake in 1896 by the late M. W. Gorman.

3. *Ranunculus Populago* Greene. Stem solitary from a fascicle of fibrous roots; leaves round reniform to cordate-ovate.—Rather rare toward the western border: Copeland Creek.

4. *Ranunculus Eschscholtzii* Schlecht. Stem 6-12 inches long; roundish in outline; petal about half an inch long.—Infrequent: wet rocks at base of cliffs below Kerr Notch.

5. *Ranunculus occidentalis dissectus* Henderson. Henderson's Buttercup.

Plants pubescent; narrowly dissected leaves.—Rather common at lower and middle elevations; Pole Bridge; Copeland Creek.

Type collected by Lyle Wynd at Pole Bridge.

6. *Ranunculus Bongardii* Greene. Bongard's Buttercup. Stems 1 to 2 feet high; leaves shallowly 3- parted.—Sparingly on the western border: Bybee Creek meadow.

4. *Delphinium* L. Larkspur

Plant low; root tuberous. ........................................1. *D. depauperatum*
Plant tall; root fibrous. ........................................2. *D. scopulorum*

1. *Delphinium depauperatum* Nutt. Dwarf Larkspur. About a foot high with blue to purplish flowers. Yellow pine woods toward the south entrance and on open ridges on the west side.

2. *Delphinium scopulorum glaucum* Gray. Tall Larkspur. From 3-6 feet tall; blue flowers in a long raceme; more common in the vicinity of Copeland Creek crossing.

5. *Aconitum* L. Monkshood

1. *Aconitum columbianum* Nutt. Tall blue-flowered plant resembling larkspur with bulblets in the axils of the leaves: stems often weak.—Abundant and widely distributed; on nearly all streams, in meadows, bogs, etc.

6.*Aquilegia* L. Columbine

1. *Aquilegia formosa* Fisch. Common on both sides of the divide from the yellow pine woods to the rim; usually on streams or other moist places; sometimes found in the cleft of rocks on the highest crests where it is reduced in size.

7. *Caltha L. Marsh* Marigold

1. *Caltha biflora* DC. Plants with broad cordate basal leaves, and large white flowers borne on thick fleshy scapes.—Frequent toward the western border in swamps, bogs and wet stream banks.

8. *Actaea* L. Baneberry

1. *Actaea spicata arguta* (Nutt.) Torr. 2 or 3 feet high with several stems, large compound leaves, and a spray of small white flowers; berries red.—Wooded places from the yellow pines up to higher altitudes: on the highway near the south entrance.

24. Berberidaceae. Barberry Family

Shrubs; leaves pinnate, spiny. ........................................1. *Mahonia*
Herbs; leaves basal, ternate.
Calyx and corolla wanting; leaves with three sessile leaflets. ..........2. *Achlys*
Calyx and corolla present, reflexed; leaves with 3 petiolate leaflets. ....3. *Vancouveria*

1. *Mahonia* Nutt.

Stems simple; leaves in a terminal tuft. ........................................1. *M. nervosa*
Stems branched; leaves scattered. ........................................2. *M. Piperiana*

1. *Mahonia nervosa* (Pursh) Nutt. Deep woods of Redblanket canyon, and other places along the western border; woods near the southeastern corner.

2. *Mahonia Piperiana* Abrams. On the north wall of Redblanket canyon near the western border.

2. *Achlys* DC. Deer Foot

1. *Achlys triphylla* (Smith) D.C. Stems scape-like with a dense spike of small white flowers; leaves large and conspicuous.

3. *Vancouveria* Morr. & Dec.

1. *Vancouveria hexandra* (Hook.) Morr. & Dec. Flowers in an open panicle on a slender, scape-like stem.—Infrequent on the west slope. Usually in dense moist woods. Round Top; Redblanket canyon.

25. FUMARIACEAE. Fumatory Family

1. *Dicentra* Bernh.

Plants large, erect in clumps; petals united. ............1. *D. formosa*
Plants diminutive; petals none or obscure. ............2. *D. uniflora*

1. *Dicentra formosa* (Andr.) DC. Bleedingheart. Common in many places from the yellow pine woods up to the rim, the more showy and larger bunches in moist situations and along wooded streams.

2. *Dicentra uniflora* Kell. Steer's Head. Rocky slopes in the hemlock belt. Plentiful on the slope back of the Cafeteria and other similar places. Its small size and prostrate habit render it difficult to see. The common name is very appropriate.

26. CRUCIFERAE. Mustard Family

Valves of the pods 1-nerved.
  Flowers yellow; leaves pinnate, petioled.
    Pod elongate, terete; plants annual.
      Leaves dimorphic, the lower with broad lobes, the upper narrow-lobed. ............1. *Sisymbrium*
      Leaves all narrow-lobed.
        Pods ascending, an inch or more long; stems 2-3 feet high, simple, erect. ............2. *Descurainia*
        Pods spreading, curved upward, about half an inch long; stems several, diffuse. ............3. *Nasturtium*
        Pods somewhat quadrangular, pointed; plant perennial. ............4. *Barbarea*
    Pod short, flat. ............8. *Draba*
  Flowers white to purple; leaves usually entire, sessile.
    Pods linear. ............5. *Arabis*
    Pods lanceolate. ............6. *Parrya*
Valves nerveless; flowers white or pinkish. ............7. *Cardamine*

1. *Sisymbrium* L.

1. *Sisymbrium altissimum* L. Jim Hill Mustard. A naturalized tumbling weed, occasionally seen along the roads in the park.

2. *Descurainia* Webb & Berth.

1. *Descurainia Richardsonii* (Sweet) Ferris. A tall introduced weed; leaves finely dissected.—Shore of lake under Cloud Cap; Annie and Sun Creek canyons.

### 3. *Nasturtium* L.

1. *Nasturtium curvisiliqua* (Hook.) Nutt. Watercress. A plant with several to many spreading stems, small yellow flowers, variably pinnately lobed leaves and short curved pods.—Occasionally along streams and other wet places, introduced: Wizard Island; Trapper Creek; Pinnacles.

### 4. *Barbarea* R. Brown

1. *Barbarea vulgaris* (L.) R. Brown. Bittercress. About a foot high with angular stems, glabrous, with elliptic basal leaves, frequently with additional small lobes along the petiol.—Along streams: Copeland Creek.

### 5. *Arabis* L. Rockcress

Seeds wingless; pods essentially terete. ........................................ 1. *A. glabra*
Seeds winged.
  Pods broad.
    Pods strictly reflexed; whole plant glabrous or nearly so. .......... 2. *A. suffrutescens*
    Pods spreading horizontally; basal leaves stellate- pubescent. ..........................
    ........................................ 2a. *A. suffrutescens* var. *horizontalis*
    Pods erect. ........................................ 3. *A. platysperma*
  Pods narrow.
    Basal leaves ciliate; pods reflexed; seeds winged all around. ........ 4. *A. rectissima*
    Basal leaves not ciliate.
      Basal leaves spatulate, obtuse; pods usually horizontal; plants low. ............
      ........................................ 5. *A. Lemmonii*
      Basal leaves linear to lanceolate, acute; pods reflexed; plants tall. ...............
      ........................................ 6. *A. Holboellii* var. *secunda*
  Pods ascending or erect.
    Plants tall; caudex simple with few branches. ...... 7. *A. Drummondii* var. *interposita*
    Plants low; caespitose; caudex with several to many branches. .......... 8. *A. Lyallii*

1. *Arabis glabra* (L.) Bernh. Tower Mustard. A tall (2 or more feet high), erect, usually not branched, mustard-like plant; stem-leaves broadly-lanceolate, entire; pods slender, 3-4 inches long, straight and strictly erect.—Common along streams: Annie Creek, Sun Creek, Vidae Falls, etc.

2. *Arabis suffrutescens* Watson (*A. dianthifolia* Greene). Stems rather low, several from a somewhat woody base; basal leaves narrow and usually glabrous; pods pendulous, few.—Dry, rocky situations.

The type of Greene's species Coville 1511, Crater Lake, 1902.

2a. *Arabis suffrutescens horizontalis* (Greene) Rollins. Differing from the type in having stellate-pubescent basal leaves and with a longer fruiting raceme and horizontally spreading pods.

Greene's species was based upon Coville and Applegate 334, Crater Lake, 1897.

3. *Arabis platysperma* Gray. The numerous stems commonly about 6 inches high from a woody base, mostly glabrous; basal leaves oblanceolate, glaucous; pods broad and flat, mostly erect.—Common about the rim in pumice sand and rocky crests.—Rim campground, Pole Bridge, Wizard Island, etc.

4. *Arabis rectissima* Greene (*A. Wyndii* Henderson). Stem usually

simple, 8-30 inches high; the basal leaves more or less hispid and ciliate; the glabrous pods strictly reflexed.

Wynd's 2322, Crater Lake, 1928, is the type of Henderson's species.

5. *Arabis Lemmonii* Watson. Stems few to many, simple, about 9 inches or less high; glabrous above; basal leaves broadly spatulate, rounded at the apex, with a dense and fine stellate pubescence; pods horizontal or more or less pendent.—Dry rocky places about the upper areas, as around the rim and Mt. Scott.

Coville and Applegate 454, Mt. Thielson, 1897, is the type of *A. semisepulta* Greene and is a synonym according to Rollins.

6. *Arabis Holboellii secunda* (Howell) Jepson. Stems from less than a foot to 2 feet high, slender, 1 or more from a simple or branching crown, densely and softly pubescent, canescent; basal leaves narrowly-oblanceolate, acute, often revolute, both surfaces covered by a dense and fine pubescence; pods straight, narrow and closely reflexed, pubescent.—Common and widely distributed: Watchman, Wineglass, Mt. Scott, inner wall, Vidae Falls, etc.

7. *Arabis Drummondii interposita* (Greene) Rollins. Stems one to several; pods erect or slightly spreading, about 1 mm. wide.

Mt. Thielson, August 6, 1897, Coville & Leiberg 343, type and isotype of *A. acutina* Greene. Ashland Butte, Siskiyou Mts. and Crater Lake, Cascade Mts., July 14, August 22, 1902, Cusick 2970, type and isotypes of *A. interposita* Greene.

8. *Arabis Lyallii* Watson. Dwarfed at high altitudes; basal leaves usually entirely glabrous; pods erect, straight.

Mt. Thielson, August 6, 1897, Coville & Applegate 435, type and isotype of *A. multiceps* Greene. Crater Lake National Park, Sept. 14, 1902, Coville 1504, type of *A. amerifolia* Greene.

In this difficult genus much confusion exists. The present treatment is based upon that of Reed C. Collins as given in his "The Genus Arabis L. in the Northwest" in Research Studies, Washington State College vol. 4, March. 1936.

### 6. *Cardamine* L. Bittercress

Leaves simple, individed. .......... 1. *C. bellidifolia*
Leaves pinnately lobed or divided. .......... 2. *C. pennsylvanica*

1. *Cardamine bellidifolia pachyphylla* Coville & Leiberg. Dwarf, 2-6 inches high, with long-stalked, ovate leaves; short scape-like stems and purplish to white flowers.—Flowering early on the upper slopes: Watchman; Union Peak; Mt. Scott; Wizard Island.

The type collection made by Coville & Leiberg at Crater Lake in 1896.

2. *Cardamine pennsylvanica* Muhl. Leaflets mostly oblong to linear.—Wet places: rare near and southeast of headquarters; common along Sand Creek.

### 7. *Parrya* R. Brown

1. *Parrya cheiranthoidea* (Nutt.) Jepson (*P. Menziesii* (Hook.) Greene). The showy purple flowers on naked spreading stems about 6 inches long; pods

broad, flat and pointed, few seeded; the densely tomentose, spatulate leaves caespitose.—Infrequent on high rocky crests.

8. *Draba* L.

1. *Draba nivalis elongata* S. Wats. A rosette of leaves with a slender bunch of flowering stems, 3 or 4 inches high; flowers bright yellow; pods linear-lanceolate, about half an inch long.—Found only on the dripping cliffs south of Kerr Notch.

### 27. Droseraceae. Sundew Family

1. *Drosera* L.

Leaves orbicular or broader than long. ........ 1. *D. rotundifolia*
Leaves much longer than broad. ........ 2. *D. longifolia*

1. *Drosera rotundefolia* L. Round-leaf Sundew.

2. *Drosera longifolia* L. Long-leaf Sundew.

While I have collected *Drosera* outside of the area, and both species are reported by Wynd, I have not seen either species within the park; nor did I find either at the State University.

### 28. Crassulaceae. Stonecrop Family

1. *Gormania* Britton

1. *Gormania Watsonii* Britton. (*Cotyledon oregonensis* S. Wats.) Common on rocks throughout the upper area. A low plant with thick, blunt, fleshy leaves and clustered whitish flowers, growing in colonies on rock ledges.

### 29. Saxifragaceae. Saxifrage Family

Shrubs.
  Leaves alternate. ........ 1. *Ribes*
  Leaves opposite. ........ 2. *Philadelphus*
Herbs.
  Staminodia present; carpels 3 or 4, united. ........ 3. *Parnassia*
  Staminodia none; carpels 2, distinct above.
    Stamens 10.
      Ovary 2-celled. ........ 4. *Saxifraga*
      Ovary 1-celled.
        Petals entire, almost filiform. ........ 5. *Tiarella*
        Petals laciniate or toothed.
          Petals white or pink, clawed; styles 3. ........ 6. *Lithophragma*
          Petals red, sessile; styles 2. ........ 7. *Tellima*
    Stamens 5.
      Petals cleft or pinnatifid. ........ 8. *Mitella*
      Petals entire, or lacking. ........ 9. *Heuchera*

1. *Ribes* L. Gooseberry. Currant

Stems without thorns or prickles (except No. 4); berry spineless; flowers in racemes.
  Currants.
  Calyx-tube cylindric or campanulate.
    Flowers pinkish-white.
      Calyx-tube cylindric; berry crimson. ........ 1. *R. cereum*
      Calyx-tube campanulate. ........ 2. *R. viscossissimum*
    Flowers pink or red. ........ 3. *R. sanguineum*

Calyx-tube rotately spreading.
  Stems prickly; berry black. ................................................................4. *R. lacustre*
  Stems smooth; berry red. ........................................................5. *R. erythrocarpum*
Stems with thorns; peduncles mostly 1-3 flowered. Gooseberry.
  Styles hairy; ovary and berry glabrous and spineless. ................................6. *R. inerme*
  Styles glabrous; berry spiny.
    Anthers lanceolate, apiculate; stamens much longer than the petals. 7. *R. cruentum*
    Anthers oval or elliptic, not apiculate.
      Stamens scarcely exceeding the petals; calyx greenish-white; leaves pubescent. ....................................................................................8. *R. binominatum*
      Stamens twice as long as the petals; calyx red; berry with very short glandular spines; leaves glabrous or nearly so. ....................................9. *R. Lobbii*

1. *Ribes cereum* Dougl. Waxy Currant. A much branched, densely clumped bush with gummy, fragrant, shallowly-lobed leaves and long, tubular white or pinkish flowers and yellowish-red berries.—Widely distributed in dry open situations and at all altitudes; from the ponderosa pine woods at the south entrance to the summit of Mt. Scott.

2. *Ribes viscosissimum Hallii* Janez. Gummy Currant. Usually several feet with comparatively few ascending branches, with rather large 3-lobed leaves and broadly-tubular greenish-white flowers more or less streaked with pink; ovary glabrous; berry black with a bloom.—Common from the lower levels up to the rim. Usually in forested areas and best developed where moisture conditions are more favorable; many places on both sides of the divide.

3. *Ribes sanguineum* Pursh. Flowering Currant. Few to several upright slender branches; leaves green above, pale pubescent below; the cluster of flowers red; berries blue-black with a bloom.—Very rare, barely entering the park in the moist woods in the canyon of Redblanket Creek at the southwest corner.

4. *Ribes lacustre* (Pors.) Poir. Prickly Currant. Stems prostrate or ascending, armed with spines and numerous bristly prickles; leaves glabrous; berry black.—Abundant along streams, in wet meadows and swamps, but sometimes found in dry places. Draped over wet rocks near the bottom of the lake trail.

5. *Ribes erythrocarpum* Coville & Leiberg. Crater Lake Currant. A trailing shrub rooting at the nodes, having copper-colored flowers and red berries. —Common everywhere in the upper forested areas; the dominant shrub in the hemlock forest where its creeping stems carpet large areas; less abundant in the lodge-pole woods and infrequent among the white-bark pines above the hemlocks. The type specimens were collected at Crater Lake in 1896. Outside of the park area the plant is known westward to the Rabbit Ears and Huckleberry Mountains and southward to Four Mile Lake. Eastward it occurs about the summit of Yamsay Mountain beyond the Klamath Marsh.

6. *Ribes inerme* Rydb. Erect bushes much resembling the cultivated gooseberry with wine-colored, pleasantly acid berries.—Only known near the southern border on the Klamath side: Annie Creek near the south entrance.

7. *Ribes cruentum* Greene (*R. Roezlii cruentum* [Greene] Jepson). The thorny branches widely spreading; leaves, calyx and ovary glabrous; flowers

red and fuchsia-like; berries covered with nonglandular spines and without pubescence.—Rare: lower Redblanket canyon; Crescent Ridge.

8. *Ribes binominatum* Heller. Siskiyou Gooseberry. Stems trailing; leaves pubescent; flowers villous, greenish; berries covered with unequal spines, usually glandular.—Not common: shady side of Annie Creek canyon and upward.

9. *Ribes Lobbii* Gray. Lobb's Gooseberry. A bush with stiff thorny branches, pendulous red flowers and berries covered with short glandular spines; leaves more or less glandular-pubescent.—Rare on dry ridges on the western border: Divide Spur; Crescent Ridge.

### 2. *Philadelphus* L. Syringa

1. *Philadelphus Lewisii* Pursh. Syringa. A tall shrub with opposite, ovate, usually entire leaves, with blade about 2 inches long and a loose panicle of large, showy, white, fragrant 4-parted flowers.—Very rare in our area in the southwest corner. In late spring this most attractive shrub may be seen in full flower along the Medford road below Prospect.

### 3. *Parnassia* L. Grass of Parnassus

Petals small, broad. ........................................1. *P. palustris*
Petals large, not so broad, fimbriate. ........................................2. *P. intermedia*

1. *Parnassia palustris* L. Petals not clawed, many veined; leaves orbicular, cordate or subcordate, petioles slender, not more than twice as long as the blade.

2. *Parnassia intermedia* Rydb. Petals slightly clawed; leaves abruptly narrowed at the base, about the same length as the petiole.

### 4. *Saxifraga* L. Saxifraga

Stems with leaves all basal.
  Plants with large oblanceolate, dentate leaves. ........................................1. *S. oregana*
  Plants with ovate entire leaves. ........................................2. *S. nidifica*
  Plants with orbicular crenate leaves. ........................................3. *S. Mertensiana*
  Plants with oblanceolate leaves, the outer part dentate; stems bracteate. ........................................4. *S. ferruginea*
Stems leafy; caespitose, alpine plants. ........................................5. *S. Tolmiei*

1. *Saxifraga oregana* Howell. Stem stout, 2-3 feet high; flowers in small thick clusters.—Annie Creek below Pole Bridge Creek.

2. *Saxifraga nidifica* Greene. About 6 inches high; leaves 1-2 inches long by half as broad, glabrous; flowers clustered near the end of the stipe-like stem.—Rare: Vidae Falls.

3. *Saxifraga Mertensiana* Bong. Filaments white and petal-like; panicle open, often bearing bulblets in the axils.—Rare except in the high wet cliffs below Kerr Notch.

4. *Saxifraga ferruginea* Graham. Much branched from the base; inflorescence loose; plant 6 inches to a foot or more high.—Wet places: spring west of headquarters, wet cliffs below Kerr Notch, Whitehorse Bluff, etc.

5. *Saxifraga Tolmiei* Torr. & Gray. Plants 2 to 4 inches high, much branched, forming dense tufts.—Near the rim, Wizard Island, Mt. Scott.

5. *Tiarella* L. False Mitrewort

1. *Tiarella unifoliata* Hook. Stems several, usually with 3-cordate lobed leaves; basal leaves with long petioles; flowers small in an elongated panicle; the unequal capsule valves conspicuous.—Moist woods on west border: Redblanket Creek, northwest corner, near west entrance, etc.

6. *Lithophragma* Nutt.

1. *Lithophragma parviflora* (Hook.) Nutt. Stem about 6 inches to a foot high; calyx clavate.—Not very common: Whitehorse Bluff; near and west of Pole Bridge, Vidae Falls.

7. *Mitella* L.

Stems leafless (occasionally a single leaf).
  Petals whitish; raceme 1-sided. ............ 1. *M. trifida*
  Petals greenish; racemes not 1-sided.
    Stamens opposite the sepals.
      Leaf-blades mainly glabrous. ............ 2. *M. Breweri*
      Leaf-blades with scattered white hairs. ............ 3. *M. ovalis*
    Stamens opposite the petals. ............ 4. *M. pentandra*
Stems leafy. ............ 5. *M. caulescens*

1. *Mitella trifida* Graham. Plant 8-15 inches high; leaves round-cordate, obscurely lobed.—Whitehorse Bluff, Lake Trail.

2. *Mitella Breweri* Gray. Plant 6-15 inches high; leaves round-cordate, shallowly lobed.—Southwest corner; near headquarters.

3. *Mitella ovalis* Greene. Petioles of leaves and bases of scapes densely pilose with reflexed hairs.—Not common: lower Redblanket canyon.

4. *Mitella pentandra* Graham. Calyx-tube purple within.—Common: headquarters; old lower camp ground; southwest of headquarters; Boundary Spring.

5. *Mitella caulescens* Nutt. (*Metalaster caulescens* [Nutt.] Howell) Stems a foot or so high, bearing 1-3 leaves; pedicels about 8 mm. long.

8. *Heuchera* L. Alum Root.

1. *Heuchera chlorantha* Piper. Stem commonly 2-3 feet high; leaves usually orbicular, cordate, shallowly lobed with long petioles sparingly covered with brownish hairs; flowers in a dense spike, petals minute or wanting. —Rare: canyon of Redblanket Creek.

30. ROSACEAE. Rose Family

Ovary superior.
  Fruit dehiscent.
    Stamens distinct; leaves simple; erect shrubs.
      Stamens well exserted; flowers rose-colored. ............ 1. *Spiraea*
      Stamens scarcely exserted; flowers creamy-white. ............ 2. *Holodiscus*
    Stamens united at base; leaves dissected; herb-like shrub. ............ 3. *Leutkea*
Fruit indehiscent.
    Pistils 10 to many; leaves compound or pinnately lobed.
      Pistils crowded, becoming drupelets, forming an aggregate berry; flowers white; stems commonly thorny. ............ 4. *Rubus*
      Pistils becoming achenes.

Calyx-lobes commonly with 5 alternate bractlets.
Style deciduous from the achene.
Receptacle a fleshy berry; leaves 3-foliate. ..............................5. *Fragaria*
Receptacle dry; leaves pinnate or palmate. ..............................6. *Potentilla*
Receptacle enclosed within the globose, berry-like calyx-tube. ......7. *Rosa*
Styles persistent; achenes and styles deflexed. ..............................8. *Geum*
Pistil only 1.
Leaves small, cuneate, 3- toothed at apex; fruit an oblong pointed achene. ..............................9. *Purshia*
Leaves larger, serrate; fruit a drupe. ..............................10. *Prunus*
Ovary inferior; fruit a berry-like pome.
Leaves compound; fruit red. ..............................11. *Sorbus*
Leaves simple; fruit purplish-black. ..............................12. *Amelanchier*

## 1. *Spiraea* L.

Flowers in narrow panicles; leaves pale beneath ..............................1. *S. Douglasii*
Flowers in corymbs; leaves green beneath. ..............................*S. densiflora*

1. *Spiraea Douglasii* Hook. . Usually several feet high with straight arrow-like stems, oblong leaves and elongated flower-clusters; calyx lobes mostly reflexed.—Not common; restricted to the lower parts: Annie Creek at south entrance, western border.

*Spiraea densiflora* Nutt. A lower shrub than the preceding with broad, flat-topped clusters of flowers; calyx-lobes erect.—Common in the upper levels in wet places: Castlecrest Garden, springs west of headquarters, Copeland Creek, etc.

## 2. *Holodiscus* Maxim.

Plant erect; leaves whitish beneath with soft hairs. ..............................1. *H. discolor*
Plant diffuse; leaves glandular-dotted. ..............................2. *H. glabrascens*

1. *Holodiscus discolor* (Pursh) Maxim. Tall bush with lax erect or ascending branches, 4-6 or more feet high; leaves ovate, coarsely serrate above, 1-3 inches long; flowers very numerous, small, white, disposed in large airy sprays.—Never seen along any of the park roads, but common about Union Creek and Prospect on the Medford highway. Rare and only in the lower part of the park: Lower Annie Creek canyon on the Klamath side, and Crescent Ridge and lower Redblanket canyon in the Rogue River watershed.

2. *Holodiscus glabrascens* (Greenman) Heller. Compared with the preceding species, lower, more intricately and stiffly branched and diffuse shrub, smaller, more or less glandular leaves and less attractive flower-clusters.—Fairly common from middle and upper elevations to the highest crests: Timber Crater, Mt. Scott, Wineglass, Union Peak, Wizard Island, etc.

## 3. *Leutkea* Bong.

1. *Leutkea pectinata* (Pursh) Ktze. Stems a few inches high, terminating in a rather close raceme of small white flowers; leaves caespitose, finely cut. —High slopes; upper Garfield Peak; crater of Wizard Island; lake trail, etc.

## 4. *Rubus* L.

Stems unarmed; leaves simple, palmately lobed.
Stems trailing, herbaceous. ..............................1. *R. lasiococcus*
Stems erect, woody. ..............................2. *R. parviflorus*

Stems prickly; leaves compound.
  Stems erect or ascending. ........................................ 3. *R. leucodermis*
  Stems trailing. ........................................ 4. *R. vitifolius*

1. *Rubus lasicoccus* Gray. Creeping Raspberry. Fruit of 2 or 3 to several red fuzzy drupelets.—Common in the hemlock forest: below the Lodge; Lake Trail; vicinity of headquarters.

2. *Rubus parviflorus* Nutt. Thimble Berry. Stems 2-3 feet high; leaves large, cordate, 5-lobed; flowers large, several, white; berry scarlet, the drupelets soon separating and falling.—Charactristic of the yellow pine belt: lower Annie Creek canyon, Wildcat Spring, lower Redblanket canyon, Sun Creek canyon.

3. *Rubus leucodermis* Douglas. Raspberry. Stems white with a bloom; leaves green above, densely white tomentose below.—Occasional in the lower areas, and sometimes seen in open situations higher up as in the vicinity of headquarters.

4. *Rubus vitifolius* C. & S. Blackberry. Sometimes more or less erect, commonly long trailing; leaves usually 3-foliate, the leaflets doubly serrate; the white, narrow petals over half an inch long; berries black and of fine flavor. —Low altitude and not common: coniferous woods, north canyon wall of lower Redblanket canyon.

5. *Fragaria* L. Strawberry

1. *Fragaria virginiana platypetala* Hall. A few inches high; leaflets glabrous and glaucous above, lighter below and more or less pubescent; berries about one-fourth inch in diameter.—Yellow pine and lodge-pole pine belts: south entrance, Copeland Creek, Wheeler Creek.

6. *Potentilla* L.

Leaves pinnate; herbage glandular pubescent. ........................................ 1. *P. glandulosa*
Leaves palmate.
  Leaflets 5-7, pale beneath. ........................................ 2. *P. gracilis*
  Leaflets 3, equally green on both sides. ........................................ 3. *P. flabellifolia*
Flowers white, leaves pinnate with 15-20 leafflets, or less. ........................................ 4. *P. Douglasii*

1. *Potentilla glandulosa* Lindl. Glandular Fivefinger. Stems many, erect, about 8 inches to a foot or more high; basal leaves long, many flowers half an inch across or larger.—Common from the yellow pine woods up to the highest crests: about headquarters, south entrance, Vidae Falls, Mt. Scott, Union Peak, Copeland Creek, etc.

2. *Potentilla gracilis* Dougl. Stems stout, erect, a foot or more high; leaves dark green above, whitish pubescent below; flowers many in a large loose cyme.—Reported by Wynd. Common southward outside of the park.

3. *Potentilla flabellifolia* Hook. Stems slender, more or less spreading, around 6 inches high; leaves few, mostly basal; leaflets fan-shaped; flowers bright yellow.—Rather frequent in the upper forested areas in moist places: hemlock forest west of headquarters, Patten Creek.

4. *Potentilla Douglasii* (Lindl.) Greene (*Horkelia fusca* Lindl.). Stems few to several, the leaflets rather small, somewhat wedge-shaped and toothed at

or near the apex; flowers small, with white petals and bluish calyx.—Not common in the park: exposed slope at Pole Bridge.

7. *Rosa* L. Rose

1. *Rosa gymnocarpa* Nutt. Naket-fruit Rose. Slender, ascending, from densely armed to nearly free from prickles; flowers an inch or more across.—Yellow pines, Annie Creek.

8. *Geum* L.

1. *Geum macrophyllum* Willd. Big-leaf Avens. Stems mostly single, rough, 2 or 3 feet high; the pinnate leaves several inches long with a large terminal lobe, the lateral ones successively smaller downward with smaller ones between; flowers about half an inch broad, yellow; achenes hairy with hooked tails.—Along streams in lower and middle elevations: lower Annie Creek, Copeland Creek crossing.

9. *Purshia* DC. Bitter Brush. Antelope Brush

1. *Purshia tridentata* (Pursh) DC. Much branched bush, dark colored, with cuneate, tridentate leaves and fragrant yellow flowers; mature fruit with red, mucilaginous juice.—Abundant in the lower yellow pine woods, especially at the south entrance where it continues outside the park, covering the open flats; yellow pine woods northeast.

10. *Prunus* L. Plum. Cherry

1. *Prunus emarginata* (Dougl.) Walp. Bitter Cherry. Bush several to 8 or 10 feet high, sometimes tree-like, forming thickets. Flowers in racemes; drupe dark-red.—Common up to middle elevations. Abundant along the Klamath road toward the south entrance.

11. *Sorbus* L.

1. *Sorbus cascadensis* G. N. Jones. Tall many stemmed, smoth shrub with long pinnately divided leaves, the leaflets finely serrate except at the base; corymbs of white flowers; fruit red, attractive.—Often along streams or in open woods, or rocky exposed slopes. Yellow pines toward south entrance, Castlecrest Garden and slope above.

12. *Amelanchier Medic.* Service Berry

1. *Amelanchier florida* Lindl. Tall erect shrub with commonly broadly elliptic leaves over an inch long, sharply and finely serrate above the middle; flowers in white clustered racemes; fruit a dark, seedy berry.—Yellow pine woods, often along streams, and on exposed upper ridges and slopes.—Vicinity of south boundary, Garfield Peak trail, west slope.

31. LEGUMINOSAE. Pea Family

Flowers in racemes.
- Leaves palmate with 5 or more leaflets. ........ 1. *Lupinus*
- Leaves pinnate, ending in tendrils.
  - Style hairy all around the summit. ........ 2. *Vicia*
  - Style hairy on the upper side only. ........ 3. *Lathyrus*

Flowers in heads or in umbels or solitary.
Leaves palmate with 3 leaflets. ........ 4. *Trifolium*
Leaves pinnate without tendrils. ........ 5. *Hosackia*

### 1. *Lupinus* L. Lupine

Plants tall, erect, relatively smooth.
Plants of wet ground.
Stem fistulous; keel not ciliate. ........ 1. *L. polyphyllus*
Stem not fistulous; keel ciliate. ........ 2. *L. latifolius*
Plant of dry ground; keel not ciliate. ........ 3. *L. Andersonii*
Plants low, caespitose, hairy.
Racemes nearly capitate, the peduncles usually curved or bent. ........ 4. *L. Lyallii*
Racemes elongated; peduncles borne on leafy stems. ........ 5. *L. lepidus*

1. *Lupinus polyphyllus* Lindl. Swamp Lupine. Stems usually simple; very tall, up to 5 or 6 feet; the dense racemes over a foot long; leaves with long petioles and commonly a dozen or more leaflets.—Rare along the lower part of Redblanket Creek near the south border.

2. *Lupinus latifolius ligulatus* (Greene) C. P. Smith. Klamath Lupine. Stems commonly several to many, branched above, 2 or more feet high.—Common along streams, margins of meadows: Castlecrest Garden, Trapper Creek, Copeland Creek, etc.

3. *Lupinus Andersonii* Watson. Stem simple, branched above, a foot or more high; flowers blue or purplish to whitish.—Widely distributed in dry yellow pine and lodge-pole pine areas, and less frequent in the hemlock belt: south entrance, Pole Bridge, Pinnacles, etc.

4. *Lupinus Lyallii* Gray. A dwarfed, densely tufted, rough-hairy plant, ranging in height up to several inches, with the more or less spreading peduncles an inch or so long and exceeding the leaves; the densely-flowered head-like raceme about the same length or shorter.—Common in dry sandy open areas in middle altitudes and ranging up the slopes to the highest crests. *Lupinus Lyalli fruticulosus* is a form with a more or less woody crown.

5. *Lupinus lepidus* Dougl. Resembling the preceding in general aspect and habit, but larger, more loosely tufted, with more silky pubescence, longer petioles and racemes, and peduncles more erect but shorter than the leaves, and ranging lower in altitude.—This plant has even a wider range of forms than the preceding. This is particularly noticeable in the length of the raceme, a complete series from perhaps 2 inches to 6 inches or longer, the extreme length being found southward outside the park area where racemes a foot long can be found. In the vicinity of the south entrance, and especially along the road toward Fort Klamath, in abundance, plants with very long cylindric racemes—long enough for *Lupinus Torreyi* Gray, now usually considered a form of *L. lepidus,* the latest combination being *Lupinus lepidus Torreyi* (Gray) Jepson.

### 2. *Vicia* L. Vetch

1. *Vicia americana* Muhl. Common in lodge-pole pine woods at Copeland Creek and similar places.

3. *Lathyrus* L. Pea

2. *Lathyrus nevadensis* Watson. Commonly with the preceding.

4. *Trifolium* L. Clover

Flowers reflexed; plants glabrous.
- Stems erect; flowers pink or purplish. ........ 1. *T. Kingii*
- Stems creeping; flowers white. ........ 2. *T. repens*

Flowers erect; plants pubescent.
- Heads sessile; stipules scarious. ........ 3. *T. pratense*
- Heads pedicellate; stipules foliaceous. ........ 4. *T. longipes*

1. *Trifolium Kingii* Watson. King's Clover. Occasional along streams; near and west of headquarters.

2. *Trifolium repens* L. White Clover. The common cultivated plant so common in fields and lawns.

3. *Trifolium pratense* L. Red Clover. Cultivated. Common in Wood River valley. Reported.

4. *Trifolium longipes* Nutt. Common in wet places throughout the park: Castlecrest Garden, Copeland Creek, etc.

5. *Hosackia* Dougl.

Annual; flowers solitary. ........ 1. *H. americana*

Perennials; flowers in umbels.
- Glabrous; stems few, fistulous. ........ 2. *H. crassifolia*
- Pubescent; stems many, slender. ........ 3. *H. Torreyi*

1. Hosackia americana Nutt. Plant 4-6 inches or higher, well branched with 3 leaflets, more or less villous; flowers yellowish streaked with red.—Lower Redblanket canyon.

2. *Hosackia crassifolia* Benth. Tall hollow-stemmed plants with 9 or more broad leaflets and one-sided umbels of yellow flowers, marked with dark red.—Only noted on the canyon wall of lower Redblanket Creek.

3. *Hosackia Torreyi* Gray. Stems numerous, 1-2 feet high; petals half an inch long, the upper bright yellow.—Middle to upper altitudes along streams and boggy places; abundant in places in Annie Creek canyon.

32. Geraniaceae. Geranium Family

1. *Erodium* L'Her.

1. *Erodium circutarium* L'Her. Red-stem Filaree. Rare: Annie Creek. Introduced.

33. Linaceae. Flax Family

1. *Linum* L. Flax

1. *Linum Lewisii* Pursh. Lewis's Flax. Blue Flax. A foot or more high, several stems from a woody base, narrow leaves. Corolla blue, about an inch across.—Dry open places along Redblanket Creek below the cabin.

34. Celastraceae. Burning Bush Family

1. *Pachystima* Raf.

1. Pachystima myrsinites Raf. Oregon Boxwood. A much branched

shrub, from nearly prostrate to ascending; stems with finely serrulate, usually oval, opposite leaves; flowers minute, reddish-brown.—Forests of lower Redblanket Creek; Castle Creek at west entrance.

### 35. Aceraceae. Maple Family

Flowers in racemes; samaras hispid; leaves large. ........................1. *Acer macrophyllum*
Flowers in corymbs; samaras glabrous; leaves small. ................................2. *A. glabrum*

1. *Acer macrophyllum* Pursh. Big-leaf Maple. Large tree; leaves often 6 inches or more broad; pistillate and staminate flowers mixed in the same raceme.—The only occurrence within the park is in the Canyon of Redblanket Creek, where it extends up from the southwest corner for perhaps a mile or more.

2. *Acer glabrum* Torr. Mountain Maple. Shrub 10 feet high or higher, usually in clumps; leaves 2 or more inches broad; the several flowers in loose umbel-like corymbs, of both staminate and pistillate; sometimes the two sexes on separate plants.—Widely distributed.

*Acer glabrum Torreyi* (Greene) Smiley, may be recognized as a smaller, tufted and bushy form with smaller leaves, occupying more exposed situations. —Round Top; Wineglass; Whitehorse Bluff.

### 36. Rhamnaceae. Buckthorn Family

Fruit a black berry with 3 nutlets. ...............................................................1. *Rhamnus*
Fruit a capsule, becoming dry and splitting into its 3 carpels. ......................2. *Ceanothus*

#### 1. *Rhamnus* L. Buckthorn

1. *Rhamnus Purshiana* DC. Cascara. With us a branched shrub about 10 feet high, erect or ascending; leaves usually elliptic, about 2 inches long, serrulate; flowers very small, greenish.—Occasional along streams in the yellow pine belt and ledgy, moist hillsides in the hemlock forest: Annie Creek at south entrance; Pole Bridge; near and west of headquarters. On lower Redblanket Creek taller with larger leaves.

#### 2. *Ceanothus* L.

Erect with showy panicles.
  Leaves serrulate, evergreen, deep green and shining above. .................1. *C. velutinus*
  Leaves entire, deciduous, dull green on both sides. ............................2. *C. integerrimus*
Prostrate; leaves small, coarsely toothed toward the apex. ........................3. *C. prostratus*

1. *Ceanothus velutinus* Dougl. Snowbrush. A much branched bush, 6-8 feet high, forming large clumps and often dense thickets over large areas. The broad varnished leaves and large sprays of small white flowers add to its attractiveness.—Especially abundant along the highway through the yellow pine forest toward the south entrance, and common on ridges on the west side.

2. *Ceanothus integerrimus* H. & A. California Lilac. A tall slender branched shrub with an elongated compound panicle of usually blue or sometimes white flowers.—Not known in our limits except in the lower part of the canyon of Redblanket Creek. An abundant shrub along the Medford road down Rogue River.

3. *Ceanothus prostratus* Benth. Squaw Carpet. Spreading over the ground often rooting and forming large dense mats over considerable areas, especially in the yellow pine woods. In the higher parts it occurs only on open exposed slopes. Fine mats occur in such situations along the Garfield Peak trail.

## 37. MALVACEAE. Mallow Family

### 1. *Sidalcea* Gray

1. *Sidalcea spicata* Greene. In ours the stems are usually little more than a foot high; the small hollyhock-like flowers are reddish-pink in a dense short spike.—Very rare. An occasional clump may be found among the willows in the wet meadow of Munson Valley south of headquarters.

## 38. HYPERICACEAE. St. John's Wort Family

### 1. *Hypericum* L. St. John's Wort

Low annual, forming mats. ........................................ 1. *H. anagalloides*
Erect perennial. ........................................ 2. *H. Scouleri*

1. *Hypericum anagalloides* Cham. & Schlecht. Tinker's Penny. The leafy mats with small orange-yellow flowers are common in many places on the wet banks of streams, in meadows and bogs and other wet places.

2. *Hypericum Scouleri* Hook. Scouler's St. John's Wort. Stems erect, simple or branched above, commonly about 1 foot high; flowers bright yellow with black dotted margin.—Frequent in wet places: Castlecrest Garden, Copeland Creek crossing, lake shore under Watchman and Cloud Cap.

## 39. VIOLACEAE. Violet Family

### 1. *Viola* L. Violet

Flowers yellow.
  Leaves orbicular. ........................................ 1. *V. orbiculata*
  Leaves elongate.
    Leaf-blades short, dentate and abruptly narrowed to the slender petiole. ........
    ........................................ 2. *V. venosa*
    Leaf-blades longer, entire and attenuate to the winged petiole. ............ 3. *V. Bakeri*
  Leaves short; wet woods. ........................................ 4. *V. glabella*
Flowers purple. ........................................ 5. *V. adunca*
Flowers white. ........................................ 6. *V. Macloskeyi*

1. *Viola orbiculata* Geyer. Round-leaf Violet. A low plant with short stem, more or less ascending, the round leaves without a pointed apex; flowers yellow, somewhat purple-veined.—Rare in the moist forests of the western border. Noted only at the following stations: at stream crossing near and south of Boundary Springs, at the end of Divide Spur and along the lower part of Redblanket Creek.

2. *Viola venosa* (S. Wats.) Rydb. Dwarf upright plants with mostly basal leaves with short variously shaped and toothed blades and long, slender petioles; the small yellow flowers commonly purple-veined.—Sometimes found in openings in the yellow pine belt, more often on dry, exposed pumice slopes upward to the highest points. To be seen, for example, about the south rim and on the south slope of the Watchman.

3. *Viola Bakeri* Greene. Baker's Violet. A larger plant than the preceding, having longer entire leaf-blades with attenuate base, and usually found in grassy more or less wooded situations at middle altitudes on the west side of the divide.—Common at Copeland Creek crossing and grassy slopes just north.

4. *Viola glabella* Nutt. Wood Violet. Stems erect with large heart-shaped pointed leaves.—Common everywhere in wet places in the woods from the yellow pines upward.

5. *Viola adunca uncinulata* (Greene) Applegate n. comb. Crater Lake Violet. Stems tufted, leaves roundish and flowers purplish.—The only purple flowered violet in the park. Frequent in wet places over much of the area. This form of the western dog violet was based upon a Crater Lake collection made by myself in 1896.

6. *Viola Macloskeyi* Lloyd. Very small with scape-like peduncles and white flowers, in springy places and boggy margins of most of the streams, in lodge-pole pine and hemlock woods.—Plentiful at such places as Castlecrest Garden, springs west of headquarters and Pole Bridge.

### 40. ONAGRACEAE. Evening-primrose Family

Parts of flowers in 4's.
  Ovary 4-celled.
    Seeds hair-tufted at one end. ........................................1. *Epilobium*
    Seeds naked. ........................................2. *Clarkia*
  Ovary 2-celled, flowers small, white. ........................................3. *Gayophytum*
Parts of the flowers in 2's; fruit bur-like. ........................................4. *Circaea*

### 1. *Epilobium* L. Willow Herb

Petals entire, spreading; flowers large. ........................................1. *E. angustifolium*
Petals notched, ascending; flowers small.
  Perennials.
    Plants pallid, glabrous and glaucous. ........................................2. *E. glaberrimum*
    Plants green and not glaucous.
      Rootstocks not producing fleshy-scaly buds.
        Stems curved or ascending. ........................................3. *E. anagallidifolium*
        Stems erect, straight.
          Leaves elliptic or oblong-ovate, bright green, short petioled. ....4. *E. alpinum*
          Leaves linear to oblong or ovate-oblong, thicker, dark green, sessile. ........................................5. *E. oregonensis*
      Rootstocks producing fleshy-scaly globose winter buds. ............6. *E. brevistylum*
  Annuals.
    Plants 3-12 inches high; stems mostly simple, more or less reddish. 7. *E. minimum*
    Plants 15 inches to 3 or 4 feet tall; stems paniculately branched; bark white shreddy. ........................................8. *E. paniculatum*

1. *Epilobium angustifolium* L. Fireweed. Stems erect, 2 to 4 or 5 feet high; petioles about 6 or 7 lines long.—Dry ground up to highest crests; best developed in lower altitudes: south entrance; Castlecrest Garden; dry openings on west side.

2. *Epilobium glaberrimum* Barbey. Stems 1 to 2 feet high erect usually unbranched; very glaucous.—Annie Creek; Round Top; Garfield trail; Trapper Creek; Redblanket Creek. Var. *fastigiatum* (Nutt.) Trel., stems 8-10

inches high; leaves shorter, is found in various places, including Devil's Backbone and east shore.

3. *Epilobium anagallidifolium* Lam. 3 to 8 inches high, simple, decumbent at base, petals small.

4. *Epilobium alpinum* L. Stems slender, erect, several to many from the rootstock; petals white or pink.

5. *Epilobium oregonense* Hausskn. Petals cream-colored or pink, deeply notched.

6. *Epilobium brevistylum* Barbey. Stems simple, erect, 1 to 2 feet high; winter buds conspicuous.—South of headquarters; Copeland Creek; Bybee Creek; Castlecrest Garden; Castle Creek.

There are several varieties or subspecies in the park area.

7. *Epilobium minimum* Lindl. Stem usually simple, 3 to 10 inches high. —Dry, open slopes.

8. *Epilobium paniculatum* Nutt. Paniculately branched above, 1 to 3 or 4 feet high.—Sparingly in lower altitudes: Bybee Creek meadow.

Numbers 3, 4 and 5 very unsatisfactory.

### 2. *Clarkia* Pursh

1. *Clarkia rhomboidea* Dougl. Stem simple or more or less branched, usually less than a foot high; flowers purplish or rose-pink, commonly nearly half an inch long.—Rare: lower part of the canyon of Redblanket Creek.

### 3. *Gayophytum* Juss.

Pedicels one-fourth to as long as the capsules; branches with scattered leaves.

| | |
|---|---|
| Style a little dilated upward. | 1. *G. diffusum* |
| Style ending in a globose stigma. | 2. *G. Helleri* |
| Pedicels almost none or very short. | 3. *G. humile* |

1. *Gayophytum diffusum* T. & G. Slender and much branched, from one-half to a foot or more high, the corolla 4-5 lines broad, white turning pink.—More common in dry yellow pine woods, but occurring in openings in the upper forests.

2. *Gayophytum Helleri erosulatum* Jepson. About 6 inches high, branches spreading, grayish and more or less hairy; flowers very small, turning red.—Not common: lower Annie Creek.

3. *Gayophytum humile* Juss. Only a few inches high, simple or with a few ascending branches, the upper leaves crowded; flowers minute.—Dry upper slopes, infrequent: top of Round Top, southwest area.

### 4. *Circaea* L. Enchanter's Nightshade

1. *Circaea pacifica* Asch. & Mag. Glabrous, usually simple stems, commonly 6-15 inches high; leaves mostly ovate, cordate at base, acuminate, 1 or 2 inches long; the white flowers minute.—Delicate plants of moist shady places; uncommon: lower Annie Creek.

## 41. Araliaceae. Aralia Family

### 1. *Oplopanax* Koch

1. *Oplopanax horridum* (Sm.) Miquel. Devil's Club. Tall, thick stemmed shrub with very large leaves; the whole plant, including the leaves, covered with prickles.—In a forest bog, at the monument marking the northwest corner of the park, is a considerable colony of this well-named plant, which as far as I know, is the only occurrence. This seems to be southern limit of the species in the Cascades.

## 42. Umbelliferae. Parsley Family

Plants low or of medium height, usually less than a foot high.
  Flowers yellow.
    Fruit with hooked bristles, not ribbed. ....................1. *Sanicula*
    Fruit smooth, flat and broad, ribbed. ....................2. *Lomatium*
Plants tall, usually more than a foot and a half high.
  Flowers white.
    Fruit ribs not winged; leaves ternately decompound, finely lobed.
      Ribs bristly; fruit linear. ....................3. *Osmorrhiza*
      Ribs smooth; fruit broad. ....................4. *Ligusticum*
    Fruit winged.
      Flowers in dense head-like umbellets. ....................5. *Sphenosciadium*
      Flowers in pedicelled umbellets.
        Fruit with lateral wings.
          Leaves ternately compound, pubescent. ....................6. *Heracleum*
          Leaves simply pinnate, glabrous. ....................7. *Oxypolis*
        Fruit with wings all around; leaves ternately compound. ....................8. *Angelica*

### 1. *Sanicula* L.

1. *Sanicula bipinnata* H. & A. A strongly aromatic herb, commonly a foot high, more or less, usually simple below; leaves ternately compound, finely dissected; the minute yellow flowers congested into very small heads; fruit covered with hooked bristlse.—Infrequent.

### 2. *Lomatium* Raf. Hog Fennel

Flowers mostly of the dry, open upper slopes. ....................1. *L. Martindalei*
Flowers of the dry yellow pines. ....................2. *L. triternatum*

1. *Lomatium Martindalei* Coult. & Rose. Plant glabrous; leaves toothed or pinnatifid; wings of fruit much broader than body.—Wizard Island; Red Cone; Diamond Lake Desert.

2. *Lomatium triternatum* (Pursh) Coult. & Rose. Plant finely pubescent; leaflets few, about a line broad; fruit about as broad as body.—Dry yellow pines at south entrance.

### 3. *Osmorrhiza* Raf. Sweet Cicely

1. *Osmorrhiza nuda* Torr. The glabrous stem nearly 2 feet high; the large ternately divided leaves delicate and fern-like, mostly basal, the stem-leaves very small; rays usually 3or 4, about 3 inches long; pedicels 5 lines long, bearing linear fruit of about the same length.—Common in rather dry woods: south entrance; hemlocks about headquarters.

4. *Ligusticum* L. Lovage

Leaflets small and crowded; rays 1 inch or less. ........................................1. *L. Grayi*
Leaflets larger and distant; rays 2 inches or more. ........................................2. *L. Cusickii*

1. *Ligusticum Grayi* Coult. & Rose.
2. *Ligusticum Cusickii* Coult. & Rose.

It may be that there is only one species at Crater Lake. But there are two plants of different aspects: a very tall form of the lower levels, as in lower Annie Creek canyon, growing in rather dry open situations; and a more slender plant of the upper levels, as at Castlecrest Garden, Copeland Creek, etc., growing in moister places with more shade.

5. *Sphenosciadium* Gray

1. *Sphenosciadium capitellatum* Gray. The nearly simple glabrous stems very stout, 2-3 or more feet high; leaves pinnately compound, with bladdery dilated petioles, the segments usually narrow and coarsely toothed.—A plant of stream margins and swampy places.—Bybee Creek meadow; Wheeler Creek; Redblanket Creek.

6. *Heracleum* L.

1. *Heracleum lanatum* Michx. Cow Parsnip. A tall plant with very large, lobed leaves with broad sheathing petioles, and large umbels of two-sized flowers; fruit almost orbicular, half an inch broad.—Abundant and widely distributed along streams, in wet meadows, etc.

7. *Oxypolis* Raf.

1. *Oxypolis occidentalis* Coult. & Rose. A glabrous erect plant with long pinnate leaves with leaflets serrate.—Common in very wet places: Vidae, Annie and Copeland Creeks; Boundary Springs. The plant first collected by Coville and Leiberg at the "lower camp ground" on the west side in 1896, and the type at the same place by Leiberg in 1899.

8. *Angelica* L.

1. *Angelica genuflexa* Nutt. Tall leafy-stemmed plant, 2 or 3 feet or higher; leaf divisions often deflexed; fruit nearly round.—Not common: wet margin of lower Annie Creek.

43. GARRYACEAE. Silk Tassel Family

1. *Garrya Dougl.*

1. *Garrya Fremontii* Torr. Bear Brush. Tall erect shrub (often 10 feet high) with leathery, mostly elliptical entire leaves, smooth and green above, lighter and pubescent below; the pendent catkins with silky bracts; fruit dark purple or black.—Near the western border, on the dry exposed wall of the canyon of Redblanket Creek, where it forms dense thickets.

44. CORNACEAE. Dogwood Family

1. *Cornus* L.

Flower clusters subtended by an involucre of large white bracts.
  Small tree or shrub. ........................................1. *C. Nuttallii*
  Small herb. ........................................2. *C. canadensis*
Flowers clusters without white bracts. ........................................3. *C. stolonifera*

1. *Cornus Nuttallii* Aud. Nuttall's Dogwood. Leaves commonly more or less elliptic, 3 or 4 inches long; flowers small in a dense head, surrounded by the petal-like bracts.—Only noted in the woods of lower Redblanket canyon.

Very attractive along the Medford road in autumn when the leaves turn a brilliant red.

2. *Cornus canadensis* L. Only a few inches high, with a whorl of leaves above, and a pair about the middle; flowers and white bracts like the preceding but much smaller.—On the western border: Bybee Creek and Redblanket Creek.

3. *Cornus stolonifera* Michx. Dogwood. Branches several to many from the base, purplish, several to 10 or more feet long, ascending; flowers in naked cymes; fruit white, roundish.—Apparently restricted to stream banks in the lower part of the canyon of Redblanket Creek.

## 45. Ericaceae. Heath Family

- Herbs.
  - Plants without green leaves.
    - Petals united forming a tubular or urn-shaped corolla.
      - Plant low, whitish, fleshy. .......... 6. *Newberrya*
      - Plant tall, reddish, not fleshy. .......... 5. *Pterospora*
    - Petals free from each other.
      - Pistil erect; plant fleshy, yellowish. .......... 4. *Hypopitys*
      - Pistil turned down; plant not fleshy, reddish. .......... 2. *Pyrola aphylla*
    - Petals none; stem red and white striped. .......... 3. *Allotropa*
  - Plants with green leaves.
    - Flowers in corymbs or umbels. .......... 1. *Chimaphila*
    - Flowers in racemes. .......... 2. *Pyrola*
- Shrubs or tree.
  - Fruit a berry; corolla urn-shaped.
    - Ovary inferior; leaves deciduous (in ours). .......... 12. *Vaccinium*
    - Ovary superior; leaves evergreen.
      - Tree with smooth golden bark and large leathery leaves. .......... 10. *Arbutus*
      - Shrubs with red smooth bark and smaller leathery leaves. .......... 11. *Arctostaphylos*
      - Dwarf shrubs with small leaves and red juicy berries. .......... 9. *Gaultheria*
  - Fruit a dry capsule; small shrubs.
    - Corolla saucer-shaped; leaves opposite. .......... 7. *Kalmia*
    - Corolla bell-shaped; leaves alternate. .......... 8. *Phyllodoce*

### 1. *Chimaphila* Pursh. Pipsissewa

- Leaves oblanceolate, many. .......... 1. *C. umbellata*
- Leaves ovate, few. .......... 2. *C. Menziesii*

1. *Chimaphila umbellata* (L.) Nutt. Prince's Pine. Stem usually simple, 6-10 inches or more high, leafy with several-flowered peduncles, the attractive flowers pinkish or flesh-colored, about 3 lines broad.—Common and widely distributed from the yellow pine to well up in the hemlock zone: Lower Annie Creek, Wizard Island, west slope.

2. *Chimaphila Menziesii* Spreng. Generally a smaller plant than the preceding, more branched, the pointed leaves with finer serration or sometimes

entire.—Comparatively rare: Annie Creek near south entrance, near Munson Point on west slope.

### 2. *Pyrola* L. Wintergreen

Rather low plants with mostly basal leaves and showy waxy flowers; stamens 10; fruit a 5-lobed, 5-celled capsule.

Plants with green leaves.
  Style straight, erect; stigma broad.
    Leaves mostly basal; style included. ....1. *P. minor*
    Leaves scattered; style exserted. ....2. *P. secunda*
  Style bent or curved downward; stigma narrow.
    Leaves orbicular, not white-veined. ....3. *P. bracteata*
    Leaves ovate or elliptic, white-veined. ....4. *P. picta*
    Leaves ovate to spatulate, pallid. ....5. *P. dentata*
Plants without green leaves, reddish (saprophytic). ....6. *P. aphylla*

1. *Pyrola minor* L. Scapes about 6 inches high, the roundish leaves commonly an inch in diameter, the smallish white or rose-colored flowers crowded. —Rare: moist wooded margin of Annie Creek below Pole Bridge Creek and Bybee Creek near the western border.

2. *Pyrola secunda* L. One-sided Pyrola. The leafy stems erect or more or less ascending, the ovate leaves thin and green; flowers rather small, white, in a one-sided dense raceme.—The most common species in the park, in the moister forested areas from the lower margins up to the rim on both sides of the divide and Wizard Island.

3. *Pyrola bracteata incarnata* DC. Round-leaf Pyrola. Scapes commonly a foot high; leaf-blades orbicular, minutely and distantly notched, about 2 inches in diameter, equalling the petiole; flowers often a dozen or more, pink. —Rare in the park: moist woody bank of Annie Creek opposite the south entrance; Bybee Creek.

4. *Pyrola picta* Smith. White-veined Pyrola. Scapes 6-12 inches high; leaf-blades generally ovate, acute, entire, dark green with white veins above, dull below; flowers usually greenish-white in a rather close raceme.—Forests of yellow and lodge-pole pine and hemlock: vicinity of headquarters, near south entrance.

5. *Pyrola dentata integra* Gray. Gray-leaf Pyrola. Differing from no. 4 in having longer leaves with rounded apex and always unmottled pallid in color, and usually confined to dryer situations, and apparently not reaching as high altitudes; frequent among lodge-pole pines: lower Sun Creek area. In our area the leaves are always entire.

6. *Pyrola aphylla* Smith. Leafless Pyrola. 6-8 inches or more high; the scapes often many and clustered; whole plant including the calyx reddish.—Frequent throughout the forested areas: Annie Creek near south entrance and lower Sun Creek area.

### 3. *Allotropa* Torr. & Gray

1. *Allotropa virgata* Torr. & Gray. Barber-pole. The thick erect red and white scapes often several, commonly a foot or more high; the close raceme mostly over 6 inches long; sepals whitish; stamens nearly black.—Fairly com-

mon in the dry forests: Wizard Island, east base of Mt. Scott, lower Sun Creek, northwest section.

4. *Hypopitys* Hill

1. *Hypopitys lanuginosa* (Michx.) Nutt. Pinesap. Stem thick, fleshy, sometimes in a clump of several, usually less than 6 inches high, covered with broad scales; raceme dense, head-like, drooping; whole plant yellowish-red.—Very rare in dense, dry hemlock forest: near and west of headquarters, Garfield Peak, Boundary Spring, Munson Point.

5. *Pterospora* Nutt.

1. *Pterospora andromeda* Nutt. The reddish-brown stem from 1 or 2 to several feet high, scaly, gummy with a long raceme of nodding white urn-shaped flowers; frequently in clumps.—Common and widely scattered; more abundant in yellow and lodge-pole pine woods: yellow pine woods along Annie Creek; lodge-pole pines, Copeland Creek.

6. *Newberrya* Torr.

1. *Newberrya congesta* Torr. Less than 6 inches high, densely scaly, flowers contested; whole plant white or delicately pinkish, very fleshy; the somewhat urn-shaped corollas deeply lobed and hairy within.—Extremely rare: collected by Ranger Naturalist Wayne Kartchner on the western boundary near the end of Boundary Spur. The type collected by Newberry north of Crater Lake in 1855. A very beautiful colony at south end of Lake of the Woods.

7. *Kalmia* L.

1. *Kalmia polifolia* Wang. Branched shrub 1-2 feet high with thick, narnow, opposite leaves and showy bright pink or rose-purple, saucer-shaped flowers. Not very common; only in springy or boggy places in the upper forests: Castlecrest Garden, near and west of headquarters; about the hillside springs.

8. *Phyllodoce* Maxim.

Low heath-like, spreading shrubs with evergreen linear, revolute leaves; of high altitudes, mostly of rocky crests.

Corolla yellowish, short-lobed, glandular. ........................................1. *P. glanduliflora*
Corolla reddish, cleft to the middle, not glandular. ..............................2. *P. empetriformis*

1. *Phyllodoce glanduliflora* (Hook.) Coville. Slope of the Watchman, inner slope of Llao Rock near summit, Devil's Backbone and along the trail on the east slope of Union Peak.

2. *Phyllodoce empetriformis* (Smith) D. Don. Not seen within the park area, although common on Mts. Thielsen and Bailey where I have collected it. Listed by Wynd, his no. 2390 Llao Rock.

9. *Gaultheria* L.

Leaves oval or rounded, near half an inch long. ...................................1. *G. humifusa*
Leaves ovate, acute, about an inch long. ............................................2. *G. ovatifolia*

1. *Gaultheria humifusa* (Graham) Rydb. Very dwarfed and low, often forming close mats; flowers white; berries red.—Rare: exactly on the north boundary line at Boundary Spring; the wet, mossy stream bank is carpeted with this little shrub. Another station in a similar situation is in the deep wooded canyon of Annie Creek above the mouth of Pole Bridge.

2. *Gaultheria ovatifolia* Gray. A larger plant than the preceding and more inclined to grow erect. Also not common in our area, but abundant westward near the west entrance. It occurs around the head of National Creek and on lower Redblanket Creek.

### 10. *Arbutus* L.

1. *Arbutus Menziesii* Pursh. This fine tree enters the park at the southwest corner and extends up the canyon wall of Redblanket Creek for perhaps a mile. It does not occur elsewhere in the park.

### 11. *Arctostaphylos* Adans. Manzanita

Erect robust shrub. ........................................1. *A. patula*
Low, more or less matted shrub. ........................................2. *A. nevadensis*

1. *Arctostaphylos patula* Greene. Green Manzanita. Abundant and often forming thickets in the yellow pine forests higher up on exposed ridges.

2. *Arctostaphylos nevadensis* Gray. Usually replacing the green manzanita above the yellow pine belt and extending to the highest parts. Abundant in the open rocky part of Castlecrest Garden and on brushy slopes along the Garfield Peak trail.

### 12. *Vaccinium* L. Huckleberry

Leaves entire, grayish; in swampy or boggy places. ........................................1. *V. occidentale*
Leaves serrulate, green; in dryer situations.
  Tall widely branched bushes. ........................................2. *V. membranaceum*
  Low, more or less caespitose. ........................................3. *V. caespitosum*
  Low, erect; leaves small, stems angled. ........................................4. *V. scoparium*

1. *Vaccinium occidentale* Gray. Swamp Huckleberry. About 2 feet high with numerous rather closely erect branches and a somewhat elongated wine-colored berry covered with a bloom.—Abundant toward the western border, forming dense thickets in the swamps and bogs of the streams. A typical example at Boundary Spring associated with the low willow, *Salix pseudocordata*.

2. *Vaccinium membranaceum* Dougl. Big Huckleberry. The bright green leaves thin, usually over an inch long; berries large and nearly black when mature.—This is the widely distributed common huckleberry, the berry of which is so prized by both whites and Indians, and growing in such abundance on Huckleberry Mountain near and westward from the park. Known by the Klamath Indians as "Ewam," and Huckleberry Mountain as "Ewam-can." There are some good patches in the hemlocks southwest of headquarters.

3. *Vaccinium caespitosum* Michx. Mat Huckleberry. Usually under a foot high, commonly only a few inches, more or less matted; berry blue with

a bloom; calyx nearly or quite entire.—Common in Castlecrest Garden, Vidae Falls, Annie Spring, Wheeler Creek and on the west slope. Middle and upper altitudes. Woods.

4. *Vaccinium scoparium* Leiberg. Broom Huckleberry. A foot or less in height, stems green, angled and rather loosely branched; leaves small; berry very small, red, but sometimes when fully mature very dark brown.—Abundant in lodgepole and hemlock forests: headquarters, Annie Spring, Boundary Spring, Pinnacles. Type collected at Crater Lake in 1896 by John B. Leiberg.

### 46. PRIMULACEAE. Primrose Family

Stem scape-like; leaves all basal. ........................................ 1. *Dodecatheon*
Stems leafy. ........................................ 2. *Trientalis*

#### 1. *Dodecatheon* L. Shooting Star

1. *Dodecatheon alpinum* Greene. Alpine Shooting Star. Very glabrous, with slender naked stems, a few inches to a foot high; leaves mostly narrow spatulate; the rose-purple petals reflexed exposing the blackish anthers.—Mostly in wet places in the hemlock forest: Pole Bridge; Castlecrest Garden; Copeland Creek.

#### 2. *Trientalis* L.

1. *Trientalis europaea latifolia* Torr. Star Flower. Half a foot or so high; simple with a whorl of leaves under the umbellate cluster of pink flowers.—Southwest corner.

### 47. GENTIANACEAE. Gentian Family

#### *Gentiana* L. Gentian

1. *Gentian simplex* Gray. Single-flowered Gentian. Stems simple, usually less than 6 inches high, naked with a solitary funnel-form blue flower an inch or more long.—Boggy and springy places: Copeland Creek, Trapper Creek.

Dr. J. S. Newberry collected the type in 1855, on the shore of Klamath Lake, just south of Crater Lake.

### 48. APOCYNACEAE. Dogbane Family

#### 1. *Apocynum* L. Dogbane

1. *Apocynum androsaemifolium* L. Small shrub-like herb with milky juice, opposite ovalish inch broad leaves and small pinkish tubular flowers.—More common in dry yellow pine woods: south entrance, exposed slope of Round Top.

### 49. POLEMONIACEAE. Gilia Family

Plants herbaceous.
  Leaves pinnately compound, the leaflets entire. ........................................ 1. *Polemonium*
  Leaves simple, often finely cut or deeply lobed, sometimes entire.
    Corolla lobes emarginate, small annual. ........................................ 2. *Phlox*
    Corolla lobes entire.
      Calyx lobes equal; flowers pedicelled.
        Sinus of calyx distended into a small lobe-like fold. ........................ 3. *Collomia*
        Sinus not distended.
          Leaves palmately divided into filiform lobes. ........................ 4. *Linanthus*

Leaves deeply lobed or entire. ....................5. *Gilia*
Calyx lobes unequal; flowers sessile spinose heads. ....................6. *Navarretia*
Plants with woody base.
Plants erect; leaves palmately divided, pungent. ....................7. *Leptodactylon*
Plants matted; leaves entire, linear, not pungent. ....................2. *Phlox*

### 1. *Polemonium* L. Jacob's Ladder

Tall plants of streams and swamps. ....................1. *P. occidentale*
Lower plants of dry or moist situations.
Leaflets much longer than wide. ....................2. *P. pulcherrimum*
Leaflets orbicular, rarely a little longer. ....................3. *P. shastense*

1. *Polemonium occidentale* Greene. Tall Jacob's Ladder. Stems erect, simple, leafy, 2 or 3 feet or more high, glabrous except toward the inflorescence; the blue flowers in corymbose clusters.—Common along streams and in swampy places throughout the park.

2. *Polemonium pulcherrimum* Hook. Stems several to many from the base, commonly ascending, 6 inches or more high, herbage bright green; corallas blue with a yellow throat.—Rather common in the hemlock forest: fine and abundant specimens grow under the high cliffs below Kerr Notch, and near streams such as Trapper Creek on the west slope.

3. *Polemonium shastense* Eastwood. Usually less than 6 inches high; stems numerous from a divided stout caudex, forming dense clumps; leaflets many, usually orbicular and crowded; flowers small, blue or lighter with yellow throat and tube.—Highest dry exposed slopes or in clefts of rocks: Llao Rock, Wineglass, Cloud Cap, upper slope of Wizard Island; occasionally along the Garfield Peak trail.

### 2. *Phlox* L.

Annual. ....................1. *P. gracilis*
Perennial with woody base. ....................2. *P. Douglasii*

1. *Phlox gracilis* (Hook.) Greene. Not common in the park but a widely distributed weed elsewhere.

2. *Phlox Douglasii* Hook. This handsome mat plant with its numerous purplish to nearly white flowers is in bloom in some parts of the park during the entire season, beginning in the yellow pine woods at the south entrance, following the disappearance of the snow on up to the highest points. Late in the season many especially colorful acres of the plant on open pumice flats and slopes are to be seen, notably about the north entrance.

### 3. *Collomia* Nutt.

Annuals.
Leaves entire.
Flowers yellow or salmon color, an inch or more long; stems usually simple, not branched. ....................1. *C. grandiflora*
Flowers light yellow, half an inch long; stem commonly diffusely branched. ....................2. *C. tinctoria*
Flowers light blue; stems often strict, sometimes branched. ....................3. *C. linearis*
Perennial.
Flowers deep blue; leaves broader, sharply lobed. ....................4. *C. mazama*

1. *Collomia grandiflora* Dougl. 6 inches or more high. More often seen in the yellow pine woods, but occurring on some of the upper grassy slopes.

2. *Collomia tinctoria* Kell. Inconspicuous, south entrance, often growing weed-like from the yellow pines upward; yellowsh corolla with nearly filiform tube; leaves linear to wider.

3. *Collomia linearis* Nutt. The purplish or pink flowers half an inch long in terminal cluster; stems 8 inches or more high, either strict or much branched; puberulent, sometimes glandular.—Not very comon: Redblanket canyon, vicinity of Pole Bridge.

4. *Collomia mazama* Coville. A tufted erect plant 6-8 inches high, with many bright green, sharply serrate, broad leaves and terminal clusters of deep blue flowers half an inch long or longer.—A plant that attracts immediate attention because of the color of its flowers. Found only on the west slope where it is most common in moist but well drained places near watercourses, mostly in the lodge-pole open grassy pine woods at middle elevations.—About the midle of August one can always find it in full flower on both sides of the road at the Copeland Creek Crossing, as well as at various other stream crossings on the same road. This is one of Crater Lake's most prized plants. The type was collected by Dr. Coville in 1896 during the time of the annual encampment of the Mazama mountain climbing club.

4. *Linanthus* Benth.

1. *Linanthus Harknessii* (Curran) Greene. Low, very slender annual, the filiform lobes of the leaves cut to the base (resembling whorls); flowers funelform, small, white.—Not common. Dry woods, yellow and lodge pole pines: upper waters of Castle Creek, south boundary about a mile above southwest corner.

5. *Gilia* R. & P.

Plants perennial.
  Flowers red; plants tall. ........................................ 1. *C. aggregata*
  Flowers white; plant low. ........................................ 2. *C. congesta*
Plants annual; leaves nearly filiform, entire. ........................................ 3. *C. capillaris*

1. *Gilia aggregata* (Pursh) Spreng. Scarlet Gilia. Stems 1 or several from the base, erect, sparingly branched, if at all, 1 to 2 or more feet high; leaves pinnate or bipinnate with narrow segments, mostly basal; corolla usually scarlet with slender tube and spreading, sharply lanceolate lobes.—One of the most attractive plants in the park, especially noticeable along the highway in the yellow pine woods at and above the south entrance; open spaces toward the west boundary.

2. *Gilia congesta montana* (Nels. & Ken.) Constance & Rollins. The few to many stems, more or less woolly, pinnate to trifid, the narrow lobes cuspidate, the white flowers in dense clusters.—A very striking and characteristic plant of the highest inner open slopes, deeply rooted in the dryest pumice gravel and sand such as Cloud Gap, Wineglass and Llao Rock.

3. *Gilia capillaris* Kell. Small slender, erect, only a few inches high, narrow leaves, less than an inch long; corolla small, white with a suggestion of blue; the narrow sharp-pointed calyx lobes about as long as the slender

corolla tube.—Rather infrequent. One place where this little plant can be found is in moist ledges near and southwest of headquarters. It also grows on the west slope along upper Castle Creek.

6. *Navarretia* R. & P.

1. *Navarretia divaricata* (Torr.) Greene. Stem of plant 2 or 3 inches high, often less than an inch high, bearing a bunch of small flower heads; the narrow bracts and leaf lobes spinose pointed; flowers minute, bluish.—Apparently rare except on the exposed wall of Redblanket canyon toward the west border.

7. *Leptodactylon* H. & A.

*Leptodactylon pungens* (Torr.) Nutt. Desert Gilia. The woody based stems a foot or so high, sometimes few but more commonly numerous and tufted, densely covered with very narrow lobed palmately divided rigidly pungent leaves; corolla white with long tube; flower much like the Douglas phlox. —Not occurring in many places in the park. On the narrow inner rim slope of Cloud Gap are some very large dense bunches; also on rocky slopes along the Garfield Peak trail.

50. HYDROPHYLLACEAE. Waterleaf Family

Inflorescence in scorpoid spikes or racemes. ........................................ 1. *Phacelia*
Inflorescence not scorpioid. ........................................ 2. *Hydrophyllum*

1. *Phacelia* Juss.

Leaves with a pair of reduced leaflets at base. ........................................ 1. *P. heterophylla*
Leaves entire; plants of high slopes. ........................................ 2. *P. leucophylla*

1. *Phacelia heterophylla* Pursh. Stems seevral from the base, erect, one and a half to two feet high; leaves mostly broadly elliptical with a pair of reduced leaflets at the base, basal long petioled, gradually reduced until the upper are sessile, grayish with short, thin and appressed pubescence.—Abundant in the yellow pine area toward the south entrance, in openings in the lodge-pole pines and hemlocks up to the rim; widely distributed on the west slope, Pinnacles, etc.

2. *Phacelia leucophylla* Torr. Stems usually 4 to 6 inches high, single or commonly separated below the surface into 2 to 5 or more parts; leaves mostly basal, elliptical, entire, with dense pubesecnce, and forming caespitose mats.—On the highest, dryest slopes as Llao Rock, Cloud Cap, Wineglass, etc. Occasionally such as on the lake shore below the Devil's Backbone, where the soil contains more moisture the plant takes on a more robust form, and grows taller and in larger mats.

2. *Hydrophyllum* L.

1. *Hydrophyllum albifrons* Heller. Water Leaf. Plant a foot or more high, hairy, the stems forming large clumps, leafy throughout; leaves 6 inches or more long including the long petiole, pinnately divided into deeply cleft sharp pointed leaflets; flowers in ours pure white, campanulate, half an inch or so long; stamens and style long exserted.—Along Redblanket Creek in swampy margins, otherwise infrequent. A mile or more north of Copeland Creek crossing on the wet margin of a steep hillside streamlet, east of the road, a few clumps may be found with diligent search.

## 51. Boraginaceae. Borage Family

Nutlets armed with prickles, perennials.
  Nutlets spreading, prickly all over. ........1. *Cynoglossum*
  Nutlets erect, prickly on the margin. ........2. *Hackelia*
Nutlets unarmed.
  Receptacle flat; corolla blue, tubular. ........3. *Mertensia*
  Receptacle more or less elongated; corolla white.
    Nutlets erect, attached from the base to about the middle. ........4. *Cryptantha*
    Nutlets oblique or incurved, attached about the center. ........5. *Plagiobothrys*

### 1. *Cynoglossum* L.

1. *Cynoglossum occidentale* Gray. A rough, hairy, leafy plant with several stems from a stout root, a foot or more high; leaves long lanceolate, the upper sessile; corolla about half an inch long; nutlets large and prickly all over.—A coarse leafy plant common in the dry yellow pine woods at and near the south entrance.

### 2. *Hackelia* Opiz. Stickseed

Flowers blue. ........1. *H. Jessicae*
Flowers white. ........2. *H. californica*

1. *Hackelia Jessicae* (Macgreg.) Brand. Blue Stickseed. Tall leafy plants with a cluster of almost rotate blue flowers much resembling forget-me-not; the fruit becoming burs.—Very common in many places where the ground is wet or at least moist, along streams, margins of meadows, etc., in the upper forests: around headquarters, Castlecrest Garden, and similar places.

2. *Hackelia californica* (Gray) Johnston. White Stickseed. Resembling the blue stickseed but with white flowers; comparatively rare: Bald Crater, upper Castle Creek, Wheeler Creek are localities where it grows.

### 3. *Mertensia* Roth. Lungwort

1. *Mertensia paniculata subcordata* (Greene) Macbride. The leafy stems several feet high, branched above, nearly glabrous; leaves large, oval; clusters of light blue tubular, pendent flowers. Common in the beaver dam section of Copeland Creek.

### 4. *Cryptantha* Lehm.

Rough perennial. ........1. *C. subretusa*
Small annuals.
  Plant stout; calyx with stiff bristles. ........2. *C. Torreyana*
  Plant slender; calyx with softer bristles. ........3. *C. affinis*

1. *Cryptantha subretusa* Johnston. Stout stems erect 6 inches or more high, usually several from the divided root crown; whole plant densely clothed with long stiff hairs; flowers white with yellow center, densely clustered.—Found only on the highest exposed slopes and summits: inner slope of Llao Rock, Wineglass and Cloud Cap.

2. *Cryptantha Torreyana* (Gray) Greene. Plant very hispid; stem branched from the middle, sometimes lower; leaves linear; small white flowers in an elongated spike; calyx segments very bristly. Not so common; dry open slopes: Devil's Backbone.

3. *Cryptantha affinis* Greene. Stems slender, commonly much branched; flowers minute; hairs not so stiff as in the preceding.—Common on dry ridges: near and west of Pole Bridge.

5. *Plagiobothrys* F. & M. Popcorn Flower

1. *Plagiobothrys hispidus* Gray. Low, much branched, hairy plant with close clusters of small white flowers.—Of the high pumice slopes: Wineglass.

### 52. MENTHACEAE. Mint Family

Mostly strong scented herbs with opposite leaves and 2-lipped corollas.

Calyx 2-lipped.
- The lips entire. ........................................ 1. *Scutellaria*
- The lips not entire.
  - Flowers solitary; trailing evergreen. ........................ 2. *Micromeria*
  - Flowers several, spike-like. ........................ 3. *Stachys*

Corolla regular; flowers in terminal heads. ........................ 4. *Monardella*

1. *Scutellaria* L. Skullcap

1. *Scutellaria angustifolia* Pursh. Stem mostly simple, erect, a foot or so high; leaves narrow, entire; the violet-blue flowers solitary in the axils, and an inch long.—Seen only in exposed openings on the wall of lower Redblanket canyon.

2. *Micromeria* Benth.

1. *Micromeria Chamissonis* (Benth.) Greene. Stems slender, about a foot long; leaves round-ovate.—Southwest corner of park.

3. *Stachys* L. Hedge Nettle

Few flowered whorls in the leaf axils, forming a long interrupted spike.

Corolla tube scarcely longer than the calyx. ........................ 1. *S. rigida*

Corolla tube twice as long as the calyx. ........................ 2 *S. ciliata*

1. *Stachys rigida* Nutt. Stem simple, a foot or more high, sometimes branched from the base, more or less hispid; leaves mostly oblong-ovate.—Rather common in wet or moist places: Bybee Creek meadow, Copeland Creek, Annie Creek at south entrance.

2. *Stachys ciliata* Dougl. Taller plant with broader leaves, softer pubescence and longer calyx tube.—Comparatively rare: marshy places along Annie Creek opposite the south entrance and farther up; and lower Redblanket Creek.

4. *Monardella* Benth.

1. *Monardella odoratissima* Benth. Mountain Pennyroyal. Shrub-like, strongly aromatic herb with several to many tough, leafy stems a foot or more high, forming clumps; heads of purple flowers surrounded by purplish bracts. —Only on the west side toward the border: Crescent Ridge and exposed wall of lower Redblanket canyon.

### 53. SOLANACEAE. Nightshade Family

1. *Chamaesaracha* Gray

1. *Chamaesaracha nana* Gray. Stems about 6 inches high; leaf blades

oval, an inch or so long, tapering into a petiole half as long, grayish; the rotate corolla whitish with five greenish spots at base; berry nearly half an inch thick, yellowish, nearly covered by the calyx, resembling a small ground-cherry.—Rare in the park: dry slope of Bald Crater.

### 54. Scrophulariaceae. Figwort Family

Upper lip of corolla not galeate.
  Filaments 5, 1 without anther; corolla tubular. ........................................1. *Penstemon*
  Filaments 4, the fifth stamen represented by a gland or scale.
    Annual; corolla strongly 2-lipped. ........................................2. *Collinsia*
    Perennial; corolla short, inflated, the lower lobe reflexed. ..............3. *Scrophularia*
  Filaments 4, all with anthers; corolla 2-lipped. ........................................4. *Mimulus*
  Filaments 2, both with anthers; corolla nearly rotate. ..............................5. *Veronica*
Upper lip of corolla galeate.
  Anther cells unequal, separated.
    Calyx 2-cleft, before and behind; upper lip very long and narrow, lower 3-toothed. ........................................6. *Castilleia*
    Calyx 4-cleft; upper lip of corolla narrow but not much longer than the 3-saccate lower lip. ........................................7. *Orthocarpus*
  Anther cells equal and approximate. ........................................8. *Pedicularis*

### 1. *Penstemon* Mitch.

Anthers woolly; plants low with woody base.
  Corolla purplish. ........................................1. *P. Menziesii*
  Corolla rose-pink. ........................................2. *P. rupicola*
Anthers glabrous; plants taller, herbaceous.
  Leaves entire.
    Flowers bluish or purplish.
      Flowers an inch or more long. ........................................3. *P. speciosus*
      Flowers about half an inch long. ........................................4. *P. hesperius*
      Flowers less than half an inch long, narrow, deep blue. ..................5. *P. cinicola*
  Leaves serrate.
    Flowers bluish, nearly an inch long. ........................................6. *P. Rattanii*
    Flowers yellowish, about half an inch long. ........................................7. *P. deustus*

1. *Penstemon Menziesii Davidsonii* (Greene) Piper. The prostrate woody based stems forming dense mats, often broad; the several flowered peduncles erect; corallas purplish, over an inch long; leaves mostly nearly orbicular, leathery green, entire.—Common on upper slopes, ledges and highest crests: many places around the rim, inside and out of the crater; fine examples along the Garfield trail.

2. *Penstemon rupicola* Howell. Rock-loving Penstemon. Differing from the Davidson penstemon in having glaucous, longer finely serrate leaves and somewhat larger rose-colored flowers. The habits of the two are similar and they are often found growing together at which places hybridization is sometimes evident.—On rocky ledges along the lake and Garfield Peak trails fine specimens are frequent, draped over the rocks. Even on the perpendicular face of Llao Rock large reddish spots mark the occurrence of this most attractive plant.

3. *Penstemon speciosus* Dougl. Usually the stems are a foot high, often less with us, more or less decumbent at base; basal leaves with long petioles,

stem leaves sessile; flowers few in the clusters that form the spike-like inflorescence.—Not common except on such high, open rim slopes as at Wineglass and Cloud Cap.

4. *Penstemon hesperius* Peck. From several to many erect stems from the base, forming rather narrow, compact clumps, usually over a foot high, the clusters of medium sized flowers in dense and definite whorls.—Very common in moist and wet wooded places, stream banks, meadows, etc. Especially abundant on the well watered west slope. Plentiful in Castlecrest Garden.

5. *Penstemon cinicola* Keck, ined. Stems erect, slender, a foot high, several to many from the base; the half dozen or so pairs of grayish leaves very narrow; the few to several whorls of flowers deep blue and small.—Infrequent in yellow pine woods in the vicinity of the south entrance, and other places along the south border. An occasional plant with lavender-colored flowers. Applegate 11113, south entrance, is typical.

6. *Penstemon Rattanii minor* Gray. A foot or more high, several stems from the base, glabrous; stem-leaves large, ovate, dentate, clasping, the basal narrower, petiolate; flowers pale purple, clusters long peduncled.—Not known in the park except in the lower part of Redblanket canyon, where it is fairly common on the brushy exposed wall.

7. *Penstemon deustus* Dougl. Growing in clumps of usually many stems, about a foot high; leaves grayish, glabrous, mostly broadly lanceolate, sharply toothed, sessile or some with very short petioles; flowers small, yellowsh to nearly white, the whorls close together.—Dry open rocky situations on the western border: Crescent ridge.

### 2. *Collinsia* Nutt.

1. *Collinsia parviflora* Dougl. Usually 6 inches or less in height the small purplish and white flowers solitary or few in a whorl, shorter than the pedicels.—Open yellow and lodge-pole pine woods.

### 3. *Scrophularia* L.

1. *Scrophularia californica* Cham. Figwort. Tall 2 feet or more high; leaves ovate, cordate, serrate, opposite, an inch or two broad; corolla brownish, the lower lobe reflexed, the others erect.—Rather rare: yellow pine woods along Annie Creek opposite the south entrance.

### 4. *Mimulus* L. Monkey Flower

Flowers pink or red.
- Plants and flowers large. ........ 1. *M. Lewisii*
- Plants and flowers dwarfed.
  - Corolla gradually narrowed downward. ........ 2. *M. nanus*
  - Corolla tubular, smaller. ........ 4. *M. Breweri*

Flowers yellow.
- Stems naked. ........ 5. *M. primuloides*
- Stems leafy.
  - Stems erect; leaves glabrous.
    - Plants with basal leaves as well as cauline leaves. ........ 6. *M. guttatus*
    - Plants with cauline leaves only. ........ 7. *M. Tilingii*
  - Stems weak, ascending, leaves pubescent. ........ 3. *M. moschatus*

1. *Mimulus Lewisii* Pursh. Lewis's Monkeyflower. Stems numerous, 1-2 feet high; flowers rose-pink, about an inch and a half long.—Plentiful along water courses in middle and upper ranges; abundant about the boat landing.

2. *Mimulus nanus* H. & A. Dwarf Monkeyflower. From one to several inches high, stem simple or branched; corollas red, half an inch or more long, limb broad; stigma broad, crimson.—Common in upper open sandy places, especially around the rim. Many bright patches in the vicinity of the Wineglass.

3. *Mimulus moschatus* Dougl. Musky Monkeyflower. Flowers light yellow, the corolla lobes nearly equal; lower part of plant slimy-viscid. The specific name given by David Douglas because of the musky odor of the plant as he found it. It is almost without scent in our area.

4. *Mimulus Breweri* Gray. Brewer's Monkeyflower. Plant from an inch to several inches high, simple or branched; corolla reddish, not very irregular, the expanded part only about a line wide with narrow tube; leaves mostly linear.—Common in many places among the rocks, appearing in great numbers soon after the disappearance of the snow.

5. *Mimulus primuloides* Benth. Low plants with clustered basal leaves, stipe-like, slender stems and surface stolons.—Bogs, meadows and wet stream margins, middle and upper levels.

*M. primuloides pilosellus* (Greene) Smiley is a dwarfed more pubescent form, often growing with the larger plant.

6. *Mimulus guttatus* DC. Common Monkeyflower. Stems a foot or two high; flowers yellow with brown spots in the throat, an inch or more long.—Very common everywhere along streams and other wet places. A very variable species. A common small form known as *M. guttatus depauperatus* (Gray) Grant.

7. *Mimulus Tilingii* Regel. Stem about 6 inches high, several from coralloid rootstocks.—Dripping rocks, east base of cliffs south of Kerr Notch.

### 5. *Veronica* L. Speedwell

Racemes several, axillary. ........................................ 1. *V. americana*
Racemes one, terminal.
  Capsule elliptical, emarginate. ........................................ 2. *V. Wormskjoldii*
  Capsule orbicular, obcordate. ........................................ 3. *V. serpyllifolia*

1. *Veronica americana* Schwein. Stems one half to one and one half feet high; leaves broad, glabrous; usually much branched and ascending.—Wet places.

2. *Veronica Wormskjoldii* Roem. & Schult. Stems slender, about 6 inches high, usually pubescent; leaves sessile; stamens and style included.—Meadow and stream margins; very common.

3. *Veronica serpyllifolia* L. Stem about 8 inches high; stamens and style exserted.—Rare, along water courses, west side.

### 6. *Castilleia* Mutis. Paintbrush

Plants with red flowers and bracts.
- Wet or moist ground plants with green and mostly glabrous foliage; leaves and bracts usually entire.
  - Stems strict, numerous and tufted on a short stout rootstock. .............. 1. *C. miniata*
  - Stem slender, weak, commonly simple, from slender underground creeping rootstocks. .............. 2. *C. Suksdorfii*
- Dry land plants with grayish pubescent foliage.
  - Stems few, rather slender; leaves minutely pilose and glandular; of lower altitudes. .............. 3. *C. pinetorum*
  - Stems several, stiff, erect; leaves densely glandular and softly pubescent; upper areas. .............. 4. *C. Applegatei*

Plants with yellowish flowers and brownish bracts. .............. 5. *C. arachnoidea*

1. *Castilleia miniata* Dougl. Stems tall, frequently 2 or 3 feet high; the broad bracts bright red; spikes rather short and dense. Very common along streams, in swamps, meadows and other wet places, or in moist woods near streams. Abundant throughout the forested areas. Castlecrest Garden. This most showy species especially abundant and tall in the open lodge-pole pine woods in the beaver dam area of Copeland Creek.

2. *Castilleia Suksdorfii* Gray. Similar to and of like habits, but readily distinguished from the last by its fewer and weaker stems, slender creeping roots; and the deep green floral bracts tipped with bright red, the color areas definitely separated, instead of being diffused as in other species.—Comparatively rare and only occurring in swampy or boggy places as in Munson valley below headquarters and in the deep canyon of Wheeler Creek opposite the ranger station.

3. *Castilleia pinetorum* Fernald. This is the characteristic paintbrush of the dry ponderosa pines. Usually the foliage has a somewhat grayish cast. The red inflorescence especially is more or less glandular viscid. Where growing in brush thickets the stems are inclined to become tall and weak.—Common along the highway toward the south entrance.

4. *Castilleia Applegatei* Fernald. The few stems commonly not more than a foot high, the spikes short and broad, deep red; the whole plant, especially the inflorescence, densely glandular and covered with scattering soft, spreading hairs. The stickiness of the plant often causing it to become sanded. —Confined to the higher, open, dry slopes and crests; common along the Garfield Peak trail; the Watchman; and about the crater of Wizard Island. The type material was collected in August 1896, on the spot now occupied by the Mt. Scott lookout station.

5. *Castilleia arachnoidea* Greenman. Not often more than 6 inches high, frequently lower, usually much branched from the base; foliage from dull green to dull purplish or brownish; floral bracts broad, brownish to dull red; corolla usually yellowish.

The many forms of the species in the Sierra Nevada, Cascade and Siskiyou Mountains present a very puzzling complex and have furnished material for the publication of new species, varieties, etc. Our Crater Lake plant apparently differs from *C. pilosa* (Watson) Rydberg in its webby-haired pubescence and very narrowly cut leaves. Dr. Jepson reduced Greenman's name to

varietal rank under the genus *Orthocarpus* under which the species *pilosus* was treated by Watson.—Very common in the upper areas, pumice slopes, etc.

7. *Orthocarpus* Nutt.

1. *Orthocarpus imbricatus* Torr. Erect, simple, often branched above, 6 inches to a foot high; bracts broad, partly purple and closely overlapping; corolla purplish, short and compact.—On the west slope: considerable colonies on the ridge just north of Copeland Creek and on the Bybee Spur.

8. *Pedicularis* L. Lousewort

Calyx split to the base in front, 2-toothed; stems branching; leaves not divided. ........................................1. *P. racemosa*
Calyx 5-cleft or toothed; stems strictly simple. ........................................2. *P. groenlandica*

1. *Pedicularis racemosa* Dougl. Many stems, spreading; herbage glabrous; corolla pink or white, the upper lip strongly incurving and prolonged into a tapering hooked beak.—Dry upper forests.

2. *Pedicularis groenlandica* Retz. Elephant Heads. Stem about a foot high, strict; corolla crimson, shaped much like an elephant's head; leaves mostly in a basal cluster, pinnately divided with toothed segments.—Boggy meadows and stream banks on both sides of the divide; abundant.

55. Orobanchaceae. Broom-rape Family

1. *Orobanche* L. Broom-rape

Plants with alternate scales instead of leaves; flowers large for the size of the plant.

Peduncles one or few; corolla purplish. ........................................1. *O. uniflora*
Peduncles many; corolla yellowish. ........................................2. *O. fasciculata*

1. *Orobanche uniflora minuta* (Suksdorf) G. Beck. Peduncles from a short nearly underground stem, 1 to 5 inches high; calyx lobes subulate.—Usually in wet, rocky places; growing on Saxifrages; not abundant.

2. *Orobanche fasciculata franciscana* Achey. Corolla pubescent and glandular.—Very dry exposed summit slopes. On the south slope of Llao Rock, at nearly 8000 feet, is a considerable colony. Here they are parasitic on the roots of *Eriogonum pyrolaefolium*.

56. Rubiaceae. Madder Family

Leaves opposite; corolla funnelform or salverform. ........................................1. *Kelloggia*
Leaves in whorls of 3 to 8; corolla rotate. ........................................2. *Galium*

1. *Kelloggia* Torr.

1. *Kelloggia galioides* Torr. Slender perennial from creeping rootstocks, a foot or so high, often profusely branching at base. Corolla pinkish, about one fifth inch long, funelform, with spreading lobes. Fruit dry covered with hooked bristles.—Common in the yellow pine woods Garfield Peak trail and elsewhere.

2. *Galium* L. Bedstraw. Cleavers

Herbs with slender square stems, and leaves in whorls.

Leaves 6 to 8 in a whorl.
  Annual. ........................................................................................1. *G. aparine*
  Perennial.
    Flowers 2 or 3; fruit hispid with long white hairs. ...............................2. *G. triflorum*
    Flowers many to numerous; fruit hispid with short scattered hairs. 3. *G. asperrimum*
Leaves in whorls of 4 or 5.
  Annual; upper leaves often reduced to 2. ..................................................4. *G. bifolium*
  Perennial.
    Fruit glabrous.
      Slender erect plants, 5 to 18 inches high. ..............................................5. *G. trifidum*
      Low matted plants, 2 to 4 inches high. ..............................................6. *G. Brandegei*
    Fruit hispid; leaves large, in fours throughout. ......................................7. *G. oregana*

1. *Galium aparine* L. Goose Grass. Stems diffuse or climbing over herbaceous plants, 1 to 3 feet long; whole herbage roughened.

2. *Galium triflorum* Michx. Sweet-scented Bedstraw. Stems smooth or somewhat scabrous on the angles.—Annie Creek, west boundary.

3. *Galium asperrimum* Gray. Stems diffuse or reclining, about 2 feet high; leaves large, scabrous along the margin; fruit small, less than a line in diameter.—Redblanket canyon.

4. *Galium bifolium* Wats. Twin-leaved Bedstraw. Stems erect simple or slightly branching, smooth and glabrous.—Wet ground: Vidae Falls, headquarters.

5. *Galium trifidum* L. Group-weed. Stem much branched and intertangled; flowers minute; fruit glabrous.—Bybee Creek meadow.

6. *Galium Brandegei* Gray. Pedicels often not exceeding the fruit in length; very leafy.—A rare mountain species, not heretofore reported from Oregon.

7. *Galium oreganum* Britton. Stems slender, numerous and radiately spreading; leaves large, distinctly 3-nerved, ciliate on the margins and on the nerves; few flowered. Redblanket canyon.

### 57. Caprifoliaceae. Honeysuckle Family

Corolla rotate to deeply saucer-shaped; regular; leaves compound; fruit berry-like.
  ........................................................................................................1. *Sambucus*
Corolla tubular or funnelform.
  Low creeping vine; flowers in pairs. ........................................................2. *Linnaea*
  Shrubs, erect.
    Berry snow-white. ....................................................................3. *Symphoricarpos*
    Berry red, pink or black; corolla irregular. ..............................................4. *Lonicera*

### 1. *Sambucus* L. Elder

Shrubs with pinnately compound leaves and numerous small flowers in compound clusters.

Cyme flat topped; berry blue with a bloom. ..................................................1. *S. caerulea*
Cyme dome-shaped; berry red. ........................................................................2. *S. racemosa*

1. *Sambucus caerulea* Raf. Blue Elderberry. A shrub 5 to 10 feet high, glabrous.—Barely entering the Park at the southwest corner, and at Crescent Ridge.

2. *Sambucus racemosa calicarpa* (Greene) Jepson. Red Elderberry. Thick clumps, 3 to 5 feet high.—Plentiful in the upper areas, especially so along the shore line of Wizard Island where, in the fall, the red berries are very noticeable. Occasionally the fruit is almost black.

2. *Linnaea* L.

1. *Linnaea borealis americana* Rehder. Twin Flower. Creeping evergreen herb with opposite leaves, and a pair of pinkish flowers.—Thick mats trailing in the forest along the western border. Especially abundant at southwest corner.

3. *Symphoricarpos* Dill. Snow Berry

1. *Symphoricarpos albus* (L.) Blake. Erect or spreading shrub; leaves round-oval to ovate, glabrous.—South entrance.

A form with densely pubescent leaves referred to *S. albus mollis* (Nutt.) Keck. This is the more common form along the south entrance, Trapper Creek, etc.

4. *Lonicera* L.

Erect deciduous shrub; flowers in pairs; leaves opposite, entire.

Corolla yellow, nearly regular. ....................1. *L. involucrata*
Corolla white, strongly 2-lipped. ....................2. *L. utahensis*
Corolla red, appearing as a single berry. ....................3. *L. conjugialis*

1. *Lonicera involucrata* Banks. Black Twinberry. The pair of berries surrounded by large reddish bracts.

2. *Lonicera utahensis* Wats. White Flowered Twinberry. Fruit wine-colored. Used by the Fort Klamath people as a sauce; called by them "Cranberry."—Very rare in the park: Boundary Springs.

3. *Lonicera conjugialis* Kell. Red Twinberry. Fruit red; lower lip of corolla deflexed, throat filled with white hairs.

58. VALERIANACEAE. Valerian Family

1. *Valeriana* L. Valerian

1. *Valeriana sitchensis* Bong. Stems 2-3 feet high with a flat terminal cluster of white flowers; leaves deeply parted into several irregular lobes.—In the upper area on both sides of the divide very abundant along streams, bogs, etc.

In dry situations, higher up, such as along the Garfield Peak trail, sides of Union Peak, is another form, lower and more pubescent, and lighter green color. This is the type of Piper's *Valeriana puberula* based on Coville & Applegate 340, Castle Crest (Garfield Peak). This seems to be identical with Heller's *V. californica,* and is here written *V. sitchensis californica* (Heller). Applegate.

59. CAMPANULACEAE. Bell-flower Family

Flowers all alike, large. ....................1. *Campanula*
Flowers of two kinds, very small. ....................2. *Heterocodon*

### 1. *Campanula* L. Bell-flower

Stem leaves sessile or nearly so. ........................................................ 1. *C. prenanthoides*
Stem leaves on petioles at least half as long as the blade. ........................ 2. *C. Scouleri*

1. *Campanula prenanthoides* Dur. Stem slender, 1-2 feet high; flowers clustered, blue.—Along the western border.

2. *Campanula Scouleri* Hook. Stem 6 to 12 inches high; herbage glabrous; flowers single, light blue.—Western margin.

### 2. *Heterocodon* Nutt.

1. *Heterocodon rariflorum* Nutt. Stems filiform; leaves roundish; teeth bristle-pointed.—Rare, wet places and open fields: upper waters of Castle Creek.

## 60. Compositae. Sunflower Family

Head with both ray and disk flowers (radiate).
  Herbs.
  Rays white; heads clustered. ........................................................ 1. *Achillea*
  Rays blue or purple.
    Bracts of the involucre in several overlapping series. ........................ 2. *Aster*
    Bracts in 1 or 2 series. ........................................................ 3. *Erigeron*
  Rays yellow.
    Pappus with a single row of slender bristles.
      Heads many, small. ........................................................ 4. *Solidago*
      Heads few, large. ........................................................ 5. *Arnica*
    Pappus with abundant white and soft hairs; heads few, large. ............ 6. *Senecio*
    Pappus with few scales or awns or none.
      Bracts of the involucre wrapped about an outer achene.
        Outer achenes with their bracts having narrow backs. .................... 7. *Madia*
        Outer achenes with their bracts having broad rounded backs. 8. *Hemizonella*
      Bracts not enfolding the achenes.
        Disk flowers intermingled with conspicuous scales or bracts. ....9. *Rudbeckia*
        Disk flowers without intervening scales or bracts.
          Plant woolly. ........................................................ 10. *Eriophyllum*
          Plant glandular-viscid-villous; leaves toothed. ........................ 11. *Hulsea*
          Plant smooth; leaves entire. ........................................................ 12. *Helenium*
  Shrub. ........................................................ 13. *Aplopappus*
Heads without ray flowers (discoid).
  Shrubs.
    Heads with 5-9 flowers. ........................................................ 14. *Artemisia*
    Heads with numerous flowers. ........................................................ 15. *Chrysothamnus*
  Herbs.
    Heads yellow.
      Pappus none; leaves deeply lobed. ........................................................ 14. *Artemisia*
      Pappus-bristles feathery; leaves entire, silvery. ........................ 16. *Raillardella*
      Pappus-bristles simple, not feathery. ........................................................ 5. *Arnica*
    Heads white or pink.
      Plants woolly.
        Achenes bearing stipitate glands; leaves broad, woolly beneath; pappus none. ........................................................ 17. *Adenocaulon*
        Achenes without glands; pappus present.
          Flowers all fertile, perfect and pistillate in the same head. 18. *Gnaphalium*
          Flowers dioecious.
            Central flowers of pistillate heads sterile. ........................ 19. *Anaphalis*
            Central flowers of pistillate heads perfect. ........................ 20. *Antennaria*

Pappus of flat white scales. .......... 21. *Chaenactus*
Heads with only strap-shaped flowers. Chicory Tribe.
Rays pink. .......... 22. *Stephanomeria*
Rays yellow or white.
Pappus feathery from a scale-like base. .......... 23. *Microseris*
Pappus of simple bristles or hairs.
Achenes sharp-toothed. .......... 24. *Taraxacum*
Achenes not toothed. .......... 25. *Agoseris*
Achenes narrowed above; leaves deeply lobed. .......... 26. *Crepis*
Achenes broad at summit; leaves entire or toothed. .......... 27. *Hieracium*

### 1. *Achillea* L. Yarrow

1. *Achillea lanulosa* Nutt. Plants a foot or more high, clustered; erect stems, narrowly and finely cut leaves and flat-topped head clusters.—Western border; Copeland Creek.

### 2. *Aster* L.

Ours all perennial herbs with showy flowers. The bracts imbricated in several rows. Pappus copious, of hair-like bristles.—A genus not easily separated from *Erigeron*.

Flowers with rays.
Ray flowers not more than 8. .......... 1. *A. ledophyllus*
Rays more than 8.
Very leafy to the summit, with broad and thin leaves. .......... 2. *A. modestus*
Not so leafy with rather thick and narrow leaves. .......... 3. *A. adscendens*
This last seems to run into *A. Fremontii* Gray and *A. occidentalis* Nutt., with stiffer stems and firmer and narrower leaves.
Flowers without rays. .......... 4. *A. shastensis*

1. *Aster ledophyllus* Gray. Stems erect, leafy, forming large clumps; leaves glaucous above, tomentulose below.—Very common from middle elevations to the highest crags on both sides of the divide; abundant about headquarters; usually in dry, open pumice.

2. *Aster modestus* Lindl. Whole plant pubescent or glabrate; stems slender, 2 to 3 feet high, simple, very leafy; leaves sparingly and acutely serrate; rays numerous and narrow, pale blue.—Annie Creek at south entrance; Middle Fork of Annie Creek; very wet ground.

3. *Aster adscendens* Lindl. Stems slender, rigid, a foot or more high; leaves linear to oblanceolate, cauline sessile, somewhat clasping, the basal ones narrowed to long ciliate petioles; heads rather numerous.—Copeland Creek; headquarters; Wheeler Creek.

4. *Aster shastensis eradiata* Gray. 3 to 6 inches up to a foot or more high; leaves linear to spatulate, usually toothed; stems greenish gray or reddish; bracts numerous.—Dwarfed on high, open slopes, as Llao Rock and Cloud Cap; taller at open ridge west of Pole Bridge and elsewhere.

### 3. *Erigeron* L. Fleabane

Rays usually in one series, sometimes in two; pappus of capillary bristles, fewer and more fragile than in *Aster*.

Stems more or less scape-like.
  Leaves dissected. ........................................ 1. *E. compositus*
  Leaves not dissected. ........................................ 2. *E. linearis*
Stems leafy.
  Rays inconspicuous, filiform. ........................................ 3. *E. acris*
  Rays conspicuous, much surpassing the disk.
    Cauline leaves auriculate clasping. ........................................ 4. *E. philadelphicus*
    Rootstock short and thick; leaves very smooth, thick; heads dark glandular. ........................................ 5. *E. salsuginosus*
    Rootstock slender; leaves and heads softly pubescent. ........................................ 6. *E. Aliceae*
    Leaves about an inch long, a line or less in width. ........................................ 7. *E. confinus*

1. *Erigeron compositus* Pursh. Feather-leaved Fleabane. Densely tufted plant, the stems 1 to several, scape-like, one-headed, 2 or 3 inches high.—Summit of Mt. Scott, Applegate 86, 1896; Dutton Cliff.

2. *Erigeron linearis elegantulus* (Greene) J. T. Howell. Leaves filiform, a half an inch or more long.—Inner slope of Cloud Cap.

3. *Erigeron acris debilis* Gray. Stems one or few, 3 to 6 inches high; basal leaves about 2 inches long, spatulate, stem leaves narrower, usually glabrous or sparingly hirsute.—Summit of Union Peak, Wizard Island, upper areas.

4. *Erigeron philadelphicus* L. Stems simple, 2 to 3 feet high; rays white or pink, numerous, narrow.—Annie Creek canyon, upper end of columns.

5. *Erigeron salsuginosus* Gray. Commonly 9 to 18 inches high, leaves much smaller toward the solitary or few peduncled head. The lower leaves oblanceouate, 3 to 8 inches long.—Very common about streams and other wet places throughout the upper area. A very showy species.

6. *Erigeron Aliceae* Howell. A dry timberland species. Abundant at lower elevations on the west slope, especially about Copeland Creek and similar situations, where it grows in large colonies. The stems are 2 or 3 feet high, leaves large and thin, heads with attractive light purple rays.

On the Bybee Creek spur and Redblanket canyon a smaller form with white rays and sometimes dentate leaves seems to approach *Erigeron Coulteri* Porter.

7. *Erigeron confinus* Howell. With us this plant is from 6 to 10 inches high, several to many branches from a deep root; numerous narrowly linear or spatulate-linear leaves; 15-20 narrow deep purple rays.—Confined to the western border, on rather exposed open ridges: end of Divide Spur and Crescent Ridge.

### 4. *Solidago* L. Golden Rod

1. *Solidago elongata* Nutt. Stem simple, 18 inches to 2 feet high, ending in a panicle.—Abundant throughout the moist timbered areas of the lower and middle elevations: Annie Creek at south entrance; Sun Creek; Copeland Creek, etc.

### 5. *Arnica* L.

Herbs with opposite leaves.

Rays wanting.
  Plants forming dense clumps. ........................................ 1. *A. viscosa*

Plants with simple stems.
Basal leaves mostly cordate or truncate. ....................2. *A. parviflora*
Basal leaves with long petioles. ....................3. *A. Parryi*
Rays present.
Leaves mostly cordate. ....................4. *A. cordifolia*
Leaves very short, lower with short petioles. ....................5. *A. Rydbergii*
Leaves, cauline 4-6 inches long, glabrous or glabrate. ....................6. *A. mollis*
Leaves saliently and very acutely dentate. ....................7. *A. amplexifolia*
Leaves narrow, tapering at both ends. ....................8. *A. longifolia*

1. *Arnica viscosa* Gray. Gummy Arnica. A foot or so high, very viscid-pubescent; leaves small.—Rare except on talus slope of Watchman and Hillman, and east slope of Union Peak.

2. *Arnica parviflora alata* (Piper) Bassett Maguire. A foot or less high; rather densely pubescent; leaves 2-4 inches long, mostly basal, prominently serrate.—Rim, on the south side.

3. *Arnica Parryi* Gray. Parry's Arnica. Slender, simple, one to two and a half feet high; leaves basal, ovate-oblong, petiole of the same length; cauline remote; pubescent below, glandular above.—Annie Creek, and west of headquarters.

4. *Arnica cordifolia* Hook. Stem one half to one foot high; basal and lower leaves cordate; villous toward the heads.—Common in the yellow pines and on up to the rim: south entrance, west of headquarters, west slope of Garfield Peak, Union Peak, etc.

5. *Arnica Rydbergii* Greene. Usually 6-10 inches high, sometimes higher; viscid-pubescent throughout.—Bluff near west shore, Garfield Peak, Union Peak, west of headquarters.

6. *Arnica mollis* Hook. 18 inches to 2 feet high, mostly entire leaves and 2 or 3 pairs, glabrous.—Abundant wherever there is water.

7. *Arnica amplexifolia* Rydb. Cauline leaves 3-5 pairs, ciliate; basal leaves inconspicuous.—Wet cliffs of Sedge Creek on west side, Copeland Creek.

8. *Arnica longifolia* D. C. Eaton. Cauline leaves 5 or 6 pairs, elongated-lanceolate; heads 2-4 in a corymb.—Very abundant among the slide rocks east of headquarters; shore under Cloud Cap, summit of Union Peak, Wizard Island, Devil's Backbone. One of the most common in the upper areas.

### 6. *Senecio* L. Ragwort. Groundsel

Herbs with alternate leaves. Pappus with abundant white and soft hairs.
Stems leafy throughout, 2-6 feet high. ....................1. *S. triangularis*
Stems few leaved or naked above. ....................2. *S. integerrimus*
Stems naked; leaves ovate, serrate. ....................3. *S. pseudaureus*
Stems and leaves woolly. ....................4. *S. Howellii*

1. *Senecio triangularis* Hook. Stem slender, erect; leaves oblong-ovate, cordate or truncate at base, serrulate.—Stream borders, meadows and bogs: very common everywhere.

2. *Senecio integerrimus* Nutt. Stem 1-3 feet high; leaves mostly basal, upper reduced to bracts.—Dry, yellow pines: south entrance.

3. *Senecio pseudaureus* Rydb. Stem 1-2 feet high; leaves with petioles twice as long as the blade, cauline reduced to one or two bracts.—Meadows on western border: Bybee Creek meadows and National Creek.

4. *Senecio Howellii* Greene. A foot or so high; leaves woolly on one side.—High altitudes: Cloud Cap; Wineglass.

### 7. *Madia* Mol. Tarweed

Dry land, annuals. ........................................ 1. *M. gracilis*
Wet land, perennials. ........................................ 2. *M. Bolanderi*

1. *Madia gracilis* (Smith) Keck and Clausen. Stem erect very slender, moderately viscid above; rays one and a half to two lines long, sulphur yellow. —Extreme south entrance, dry yellow pines.

2. *Madia Bolanderi* Gray. Stem stout, erect, glandular-hirsute above: rays 3-5 lines long, yellow.—Meadows, bogs: beaver dams at Copeland Creek; Bybee Creek meadow; near headquarters. Abundant.

### 8. *Hemizonella* Gray

1. *Hemizonella minima* Gray. Stems 1 and erect to several, more or less dichtomously branched, from a rosette of basal leaves. Flowers minute, yellow.—Yellow pines at south entrance.

### 9. *Rudbeckia* L.

1. *Rudbeckia californica* Gray. California Cone-flower. Stems 2 to 5 feet or higher; rays 1 to 2 inches long, yellow; disk as long as the rays, dark brown; leaves 6-12 inches long, basal and lower long petioled.

### 10. *Eriophyllum* Lag.

1. *Eriophyllum lanatum* (Pursh) Forbes. A woolly plant with many leafy stems and numerous heads with golden-yellow rays. A very variable species. Two forms of quite dissimilar appearance are found in our area: variety *achillaeoides* (DC.) Jepson has tall erect stems and pinnately parted or cleft leaves; found in the lower areas, especially abundant at the south entrance among the yellow pines. Variety *integrifolia* (Hook.) Smiley is a lower, more or less matted plant with mostly narrow entire leaves, growing at the highest elevations, summit of Mt. Scott and at Cloud Cap.

### 11. *Hulsea* T. & G.

1. *Hulsea nana* Gray. Caespitose perennial, viscid-villous; leaves crowded at the base, divisions oblong.—Cloud Cap; Llao Rock.

A more villous form with leaves scattered on short stems and shorter divisions is known as *H. nana Larsenii* Gray. This is found on the road leading through the Desert to Diamond Lake; also on Dutton ridge and Crater Peak.

### 12. *Helenium* Gray

1. *Helenium Bigelovii* Gray. Sneeze Weed. Stem 2-4 feet high; leaves mostly glabrous, sessile and decurrent on the stem, 4-10 inches long; disk

brownish; rays showy, 7 to 9 lines long.—Meadows, stream banks, bog, etc.: Bybee Meadow, Copeland Creek; on the west side.

### 13. *Aplopappus* Cass.

1. *Aplopappus Bloomeri* Gray. Bloomer's Rabbit Brush. Shrub 1-2 feet high, rounded clumps, numerous virgate stems leafy to the top; leaves an inch or so long, 2 or 3 lines wide.—Very common throughout the upper, open spaces; headquarters, Bald Crater, Timber Crater, Flat below the Lodge, Copeland Creek.

A form with filiform leaves is abundant in the yellow pine areas: Crater Peak region; Sun Creek; Annie Creek at south entrance; Pinnacles. This is known as *A. Bloomeri angustatus* Gray. The two are never found together, and seem distinct, at least here.

### 14. *Artemisia* L.

Shrub. ........................................ *A. tridentata*
Herb. ........................................ *A. vulgaris*

1. *Artemisia tridentata* L. Sagebrush. Erect, much branched shrub 3 or 4 feet high; canescent or silvery throughout; leaves 3-toothed at apex.—Seen only in one place: near the shore line just east of the Wineglass.

2. *Artemisia vulgaris ludoviciana* Hall. Stems 2 or 3 feet high; leaves white above, usually 3-cleft at apex.—Occurring only on brushy ridge west of headquarters.

### 15. *Chrysothamnus* Nutt.

1. *Chrysothamnus nauseosus speciosus* (Nutt.) Hall. A rayless shrub, 1 to 2 or 3 feet high; plants gray, tomentum thin.—Rim on Garfield trail; Pumice Point; Wineglass.

### 16. *Raillardella* Gray

1. *Raillardella argentea* Gray. Silver Flower. Scapes 1 to 4 inches high; leaves narrowly oblanceolate covered with a silvery felt.—On the higher points: Llao Rock; top of Garfield Peak; top of Mt. Scott; Timber Crater.

### 17. *Adenocaulon* Hook. Silver Green

1. *Adenocaulon bicolor* Hook. Upper portion of stem and panicle covered with small glands; leaves broad, white woolly beneath.—Lower up to middle elevations: south entrance; west side.

### 18. *Gnaphalium* L. Cudweed

1. *Gnaphalium microcephalum* Nutt. Small-headed Everlasting. Stems several, erect, 1 or 2 feet high, ending in a much branched panicle; herbage densely white-lanate.—Rather rare: west shore; south entrance; shore at Wineglass.

### 19. *Anaphalis* DC. Everlasting.

1. *Anaphalis margaritacea* (L.) Benth. and Hook. Stems several from the base, 1 to 2 feet high; leaves narrow with a revolute margin; bracts of the

involucre pearly white and scarious.—Abundant from the lower areas to the rim: west shore; south entrance; Wineglass, etc.

20. *Antennaria* Gaertn.

Matted, more or less woolly herbs, the flower-heads with papery involucral bracts.

Involucral bracts pink.
  Plants low, about 4 inches; stems leafy above. ............ 1. *A. Geyeri*
  Plants taller; stems sparsely leafy above. ............ 2. *A. rosea*
Involucral bracts not pink.
  Plant tall; basal leaves broad, tomentulose beneath. ............ 3. *A. racemosa*
  Plant low; bracts green or greenish brown. ............ 4. *A. media*

1. *Antennaria Geyeri* Gray. Stems several, erect, from a woody base; herbage lanate.—Mt. Scott trail; Crater Peak region; Cloud Cap.

2. *Antennaria rosea* (D. C. Eaton) Greene. Stems erect sparsely leafy.—Ledges southwest of headquarters; Trapper Creek; Bald Top.

3. *Antennaria racemosa* Hook. Lightly woolly, becoming glabrate; flower stems 6-20 inches high; leaves densely tomentose beneath.—Near the south shore.

4. *Antennaria media* Greene. Densely caespitose.—Union Peak; Mt. Scott; near headquarters; Red Cone.

21. *Chaenactis* DC.

1. *Chaenactis Douglasii* H. & A. About a foot high, leaves cut into small lobes; heads usually several, forming a loose flat-topped cluster.

Variety *alpina* is a dwarf tufted perennial, 3 to 5 inches high.—Wineglass; Cloud Cap.

22. *Stephanomeria* Nutt.

1. *Stephanomeria lactucina* Gray. Stem erect 4 to 12 inches high from a creeping rootstock; leaves linear, or with a few salient teeth.—Fairly common in the yellow pine forest.

23. *Microseris* Don

1. *Microseris nutans* (Geyer) Schultz Bip. Stems 1 to several, leafy; leaves usually narrowly linear above.—Frequent in yellow pines at south entrance.

24. *Taraxacum* Haller

1. *Taraxacum palustre vulgare* (Lam.) Fernald. Common Dandelion. Scapes 8 to 16 inches high; leaves 6 to 12 inches long; bracts of the involucre linear, reflexed.—Annie Creek, Sand Creek.

25. *Agoseris* Raf. False Dandelion

Stems naked and scape-like, each bearing a single head.

Achenes beakless; leaves glabrous. ............ 1. *A. alpestris*
Achenes beaked.
  Leaves glaucous.

Scapes glabrous. .......... 2. *A. glauca*
Scapes pubescent. .......... 2a. *A. glauca aspera*
Leaves not glaucous.
Beak of the achene about as long as, or shorter than the body. .... 3. *A. aurantiaca*
Beak much longer than the body. .......... 4. *A. gracilens*

1. *Agoseris alpestris* Greene. Leaves from narrowly-linear to lanceolate or oblanceolate, entire or remotely toothed or pinnatifid; scapes usually 4 to 6 or 8 inches high.—Upper reaches, common.

2. *Agoseris glauca* (Nutt.) Greene. Leaves usually entire, 2 to 4 inches long, half an inch or less wide; scapes 2 to 6 inches high.—High altitude: Cloud Cap; Llao Rock.

2a. *Agoseris glauca aspera* (Rydb.) Piper. Leaves pinnatifid; scapes 4 to 6 inches high.—Yellow pine woods at south entrance.

3. *Agoseris aurantiaca* (Hook.) Greene. Leaves entire or usually so, 8 to 12 inches long; scapes 10 or 15 inches high; flowers orange, fading to purple.—Pinnacles; Redblanket Creek.

4. *Agoseris gracilens* (Gray) Ktze. Leaves mostly entire, occasionally remotely toothed; scapes 12 to 18 inches high; flowers deep orange, fading purple.—South entrance; Copeland Creek; Crater Peak; Castlecrest Garden.

### 26. *Crepis* L. Hawksbeard

1. *Crepis pleurocarpa* Gray. Plant 12 to 18 inches high; flowers yellow; leaves mostly basal.—Rare: southwest quarter.

### 27. *Hieracium* L. Hawkweed

Mostly rough-hairy perennial herbs; leaves mostly entire.

Flowers white. .......... 1. *H. albiflorum*
Flowers yellow.
Stem very leafy.
Leaves villous and tomentulose-canescent. .......... 2. *H. Howellii*
Leaves covered with long whitish shaggy hairs. .......... 3. *H. horridum*
Stems sparingly or not at all leafy.
Basal leaves glabrous; involucre hirsute with black hairs. .......... 4. *H. gracile*
Basal leaves more or less hairy.
Involucre glandular. .......... 5. *H. cynoglossoides*
Involucre not glandular. .......... 6. *H. Bolanderi*

1. *Hieracium albiflorum* Hook. Stems 1 to several, erect, nearly naked above, 1-3 feet high.—Yellow pines at south entrance; exposed slope of Round Top; open slope of Red Cone.

2. *Hieracium Howellii* Gray. Stems 1-2 feet high, stellular-pubescent; leaves spatulate to oblanceolate, usually entire.—Devil's Backbone.

3. *Hieracium horridum* Fries. Stems 4-10 inches high; herbage densely shaggy with long whitish hairs; flowers bright yellow.—Rocky places in the upper reaches: east slope of the Watchman; open slope of Llao Rock; upper Sand Creek.

4. *Hieracium gracile* Hook. Stems 6 to 12 inches high; leaves basal,

oblanceolate, nearly entire, glabrous.—Dry woods, higher elevations: Mt. Scott; Red Cone; Union Peak; near south rim.

5. *Hieracium cynoglossoides* Arv. Stems 1 or several, 1 or 2 feet high; leaves mostly basal, upper cauline few passing into bracts; flowers bright yellow, exceeding the involucre.—Yellow pine zone: south entrance.

*Hieracium cynoglossoides nudicaule* Gray is a form common at the southeast base of Round Top, Arant Point and Vidae Falls, with basal leaves, the stems naked or reduced to bracts.

6. *Hieracium Bolanderi* Gray. Stem 1 or few from base, loosely branched, 8 to 10 inches high.—Rare: Red Cone.

Dudley Herbarium,
Stanford University,
California.

PLATE 1.—Top: Yellow pine woods, southern entrance; Center: From Garfield Peak looking east. Phantom Ship in middle foreground. Mount Scott in the distance; Bottom: Annie creek canyon, rim of crater in the distance.

PLATE 2.—Upper left: *Abies lasiocarpa*, Munson Valley, south of headquarters; Upper right: Union Peak looking west, *Tsuga mertensiana* and *Abies magnifica shastensis;* Lower left: Llao Rock looking west, *Tsuga mertensiana* and *Pinus albicaulis;* Lower right: Vidae Falls, east of headquarters.

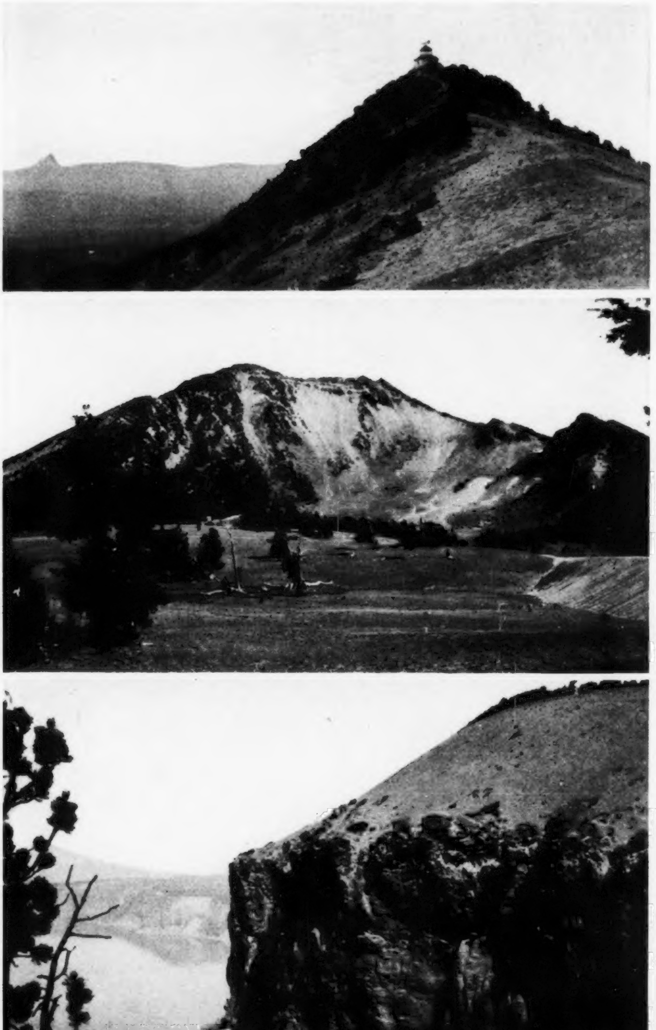


PLATE 3.—Top: Summit of Mount Scott looking north; Center: Mount Scott looking east; Bottom: Cloud Cap, *Pinus albicaulis* on left and on upper edge.

# The Status of Talinum in Alabama

W. Wolf, O.S.B.

## 1. Earlier Published Records and Evidence Material

Concerning the occurrence of the genus *Talinum* and its geographical distribution in Alabama, the most complete record available about the beginning of the present century is found in Mohr's "Plant Life of Alabama." Considering conditions and circumstances in Mohr's own time, and adding to this the particular nature of the case, Mohr's knowledge with regard to the distribution of Talinum in Alabama is to be considered as fairly ample. Four counties are cited thus (p. 496): "Clay County, Baldrock, 2200 feet. Cullman County, 800 feet *(Misses Emily* and *Mary Mohr)*. Blount County, Warnock Mountains, 1000 feet. Walker County, Clear-Creek Falls. . . . Not frequent, local."

This specific record must be supplemented by two text references, one on page 63 in connection with the xerophile forest of metamorphic hills (Piedmont), the other on page 79 in connection with the Lookout Mountain vegetation. No counties are mentioned there, but it may be inferentially surmised from the text that they are Cleburn County and DeKalb County, respectively.

Among the four definitely stated counties, there is one (Cullman Co.) about which Mohr places the responsibility upon his nieces E. and M. Mohr who, up to 1894 had for seven years resided in the immediate neighborhood of Cullman, the county seat of the respective county, and where Mohr visited at intervals with his brother. These ladies possessed a private herbarium mainly of their own collecting, but disposed of it on leaving Cullman for California, it being acquired by the Milwaukee Museum of Natural History. No Talinum specimen from Alabama is found there but, in the opinion of the writer, the absence finds a ready explanation. For private herbariums of limited extent it usually suffices to have a species represented by a single mount, irrespective of locality. Now, there is evidence that these ladies had actually collected a Talinum specimen on Warnock Mountain in Blount County—not too distant from their home even in horse-and-buggy times. Apparently, the ladies sacrificed their specimen for the benefit of the Herbarium of the Geological Survey of Alabama, where it is mounted (with no date stated) on one and the same sheet with a specimen from Clear-Creek Falls, Walker County, the latter collected by C. Mohr in July 1880. A Walker County specimen of same station and date is also extant at the U. S. National Herbarium.

Having disposed of three counties of the specified record, there remains to be discussed "Clay County, Baldrock, 2200 feet." No Baldrock specimen

exists at the Geological Survey, nor from any other station in Clay County. In fact, this part of the record creates a puzzling situation, possibly merely due to a slip of memory. It is a twofold one and concerns, first "Baldrock" itself, and then its association with Clay County. Baldrock, in bygone years, was more shrouded in obscurity than at present, even to the personnel of the Geological Survey. Mohr states the elevation of the respective habitat as "2200 feet," and, most likely, allowance is to be made for some overhead margin with regard to the absolute summit of the mountain, parallel to Mohr's station on Warnock Mountain. These would be about equal with the limit of elevation within the State.

Now, there is indeed a topographical Baldrock within the region of the Cahaba Ridges. According to C. Butts (1) this eminence of the Backbone Mountain rises 800 feet above the valley floor, and floor levels between the parallel ridges are stated as ranging between 500 and 750 feet. Thus, at best, the absolute height of the summit of this Baldrock falls short several hundred feet in comparison with the elevation of the habitat of Mohr's "Baldrock." In August 1938, Dr. Harper visited another Baldrock, but its elevation is only 800 feet above sea level. As to the second point in question, neither of said topographical Baldrocks is located in Clay County. The first mentioned is one and a half miles northwest of Cooks Springs in the southwestern part of St. Clair County, and the second one is near Almond in Randolph County. A plausible solution is presented in the following paragraph.

In the herbarium of the Geological Survey there exist two other specimens collected by Mohr, which serve as evidences to the respective generalized passages on pages 63 and 79 of the Plant Life (4), referred to before. The label of the one specimen reads in part: "Lookout Mt. Mentone, June, 1893. C. Mohr." Mentone is located in DeKalb County. But it is the other specimen that attracts particular attention relative to the previous discussion on the Baldrock situation. This specimen comes from Cheawha Mountain which has the distinction that its summit represents the highest point in Alabama, rising 2407 feet above sea level. The general spelling in the Plant Life is Chehawhaw, but this is corrected at page 845 to read Che-aw-ha. In the Geology of Alabama (1) the name is simply spelled Cheaha. Now, the label to the specimen reads in part thus: "Exposed Rocks—Flat Rock. Che-aw-haw Mts. 2200 ft. July 31, 1896 Chas. Mohr." Substituting *"Bald"* for *"Flat"* and adding the word elevation will then read *Bald Rock* 2200 feet which is equivalent to Mohr's "Baldrock, 2200 feet." There still remains the defect with regard to county. But, on account of the proximity of the location, the defect dwindles to one of minor degree. Cheawha Mountain is in the southwestern part of Cleburn County, and is only 15 miles north of Ashland, which is the county seat of adjacent Clay County.

The above is all that can be learned from the Plant Life. All in all, the record is a rather creditable one. Excluding "Baldrock" from the list of localities on account of ambiguity, there remain five definitely acceptable ones, namely, Walker, Blount, Cullman, DeKalb, and Cleburn Counties. What

is of particular significance in Mohr's records is the fact that it covers the entire east to west extent of the range within the State, so as to coincide exactly with data obtainable today. With Clear-Creek Falls in Walker County to the west and Mentone in De Kalb County near the eastern boundary of the State, the range extends practically from 85° 30′ to 87° meridians.

Additional knowledge of considerable importance is gained from other sources, even if these are extremely limited. In 1902 T. G. Harbison, (3) in his sketch on the Sand Mountain flora refers to the occurrence of *Talinum* in Jackson County. The particular station mentioned is Bryant, which is located in the extreme northeast corner of Alabama. No specimen in this connection could be located, though it may be surmised that such had been deposited at that time in the Biltmore herbarium. Even so, the authority is a most reliable one, and from recent private information it is learned that *Talinum* is in a most flourishing condition about Higdon, which is only several miles south of Bryant. Harbison's discovery established a northern landmark relative to the north-south extent of the range within the State. Of less importance are specimens distributed by Albert Ruth (coll. 1898), the locality stated being either too generalized (Lookout Mt. Ga. & Ala.), or, if specified (Valley Head), the locality is more exactly covered by Mohr's Mentone specimen—Valley Head is merely the railway stop to the mountains there in general and to Mentone in particular. Pollard & Maxon's no. 344 (1900) covers the southmost station of the Lookout Mountain, Gadsden in Etowah County, and Earle & Baker's specimen from Auburn, Lee County (1897) records the southern landmark of the range. Thus by evidence, accumulated before the year 1903. the full extent of the range from north to south had been established at that early period. It extends approximately from 32° 30′ to 35° parallels of latitude.

## 2. The Species Question

Since no Talinums have ever been found in the coastal plain, the larger of the two major geographical divisions of Alabama, the species question, therefore, becomes restricted to an Appalachian affair.

Published records as well as the specimens mentioned previously comprise Alabama plants which had invariably been determined as *Talinum teretifolium* Pursh. This is consistent with the single species concept of the Appalachian Talinums, as it prevailed unchallenged for more than a century, that is, since the establishment of said species by Pursh in 1814. The proposal of a new Appalachian species (*T. mengesii* Wolf) in 1920 (8) affected foremost the former status quo concerning the Alabama situation, because, the concept of the proposed species had been based on Alabama plants from Cullman County. (Incidentally, it eliminated also the deficiency of evidence in Mohr's record with regard to the respective locality.) Thus, while Alabama had figured with one species in previous taxonomic literature (4) it is credited with two species in more recent works (6, 7). The actual situation at present can be gleaned from the following investigation.

A first inquiry in 1919 concerning the matter in question elicited a reply from the late Dr. E. A. Smith. Somewhat later the writer had the opportunity of examining personally Mohr's herbarium material at the Geological Survey, and he found everything exactly as stated by Dr. Smith—of the four specimens, only the Walker County specimen had a flower. Contrary to expectation, the state of preservation of the "single" flower was excellent. All specific details were perfectly discernible even at a mere glance. The numerous stamens, the relative length of the long columnar style, the characteristic feature of the stigma, the large size of the flower, all represented diagnostic characters of *Talinum mengesii*. Unfortunately, this result was an isolated one, referring only to the Walker County locality. Additional information was difficult to obtain and much time passed during its accumulation.

The following is an account of later discoveries and rediscoveries in chronological succession, and also the results of determination of species in each instance:

1921. Exploration of Warnock Mountain by the late professor of Biology B. Knapke and Prof. D. Downs, in search of Mohr's Talinum habitat. Mistakenly exploring first the summit, final success resulted only from a last-minute effort at a somewhat lower elevation .......... *Talinum mengesii.*

1922. De Soto Falls near Mentone, De Kalb County. Moderately pressed and dried vegetative specimens delivered by Professor P. Niedermeier. Of no real value for identification, the specimens were shelved for the time being. On examination about 10 days later there were observed obvious indications of the plant's resistence against exsiccation. An emergency trial at revivification had the desired effect, and complete data were obtained. .......... *T. mengesii.*

1933. Georgia Mountain in Morgan County. On a botanical excursion to Georgia Mountain 10 miles east of Hartsells, Dr. R. M. Harper pointed out to the writer a Talinum habitat discovered by him on a previous occasion.......... *T. mengesii.*

1934. Shades Mountain in Jefferson County by Mr. N. A. Leeds of the Academy of Nat. Sciences in Philadelphia and Mr. H. E. Wheeler from Birmingham, Alabama. Shades Mountain is one of the parallel ridges alternating with parallel valleys, the complex of which constitutes Birmingham Valley. (At Mr. Leeds arrival at St. Bernard the next day, flowers not in anthesis the day before had opened in the dark of the vasculum) .......... *T. mengesii*

(1937. Along Coosa River about one mile below Mitchell Dam in Chilton County. Is to be discussed separately.)

1938. Eight-Acre Rock in Tuscaloosa County by Dr. R. M. Harper.......... *T. mengesii*

1938. Baldrock near Almond in Randolph County by Dr. Harper.......... *T. mengesii*

Specimens of earlier dates, reidentified:

1880. Clear Creek Falls, Walker County, by C. Mohr. (Herb. Geol. Survey; U. S. Natl. Herb.).......... *T. mengesii.*

1897. Auburn, Lee County, by F. S. Earle & C. F. Baker. (U. S. Natl. Herb.) no. 344779.......... *T. mengesii*

1898. Lookout Mt. specifically Valley Head, De Kalb County. (U. S. Natl. Herb. no. 345370; also Langlois Herb. at Cath. University of America).......... *T. mengesii*

1900. Vicinity of Gadsden, Etowah County, by C. L. Pollard & W. R. Maxon. (U. S. Natl. Herb. no. 442896. Distributed as no. 344.).......... *T. mengesii*

Type Specimens:
1920. Eight-Mile Creek, Cullman County, by W. Wolf. (Herb. St. Bernard College, no. 1668.) ........ *T. mengesii*

No evidence at disposal:
Flat Rock, Cheawhaw Mt. (Cleburn County) by C. Mohr. Herb. of Geological Survey of Alabama.—Identified by Mohr as ........ *T. teretifolium.*

Bryant, Jackson County. Published in 1902 in Biltmore Bot. Studies by T. G. Harbison, and identified by him as ........ *T. teretifolium*

Remark: According to information received through the courtesy of Mr. E. J. Alexander, of the New York Botanical Garden, there exist no *Talinum teretifolium* specimens from Alabama, all the specimens from that state belongs to *T. mengesii.*

Summing up the result of these investigations, all specimens examined were referable to *Talinum mengesii,* whenever *T. teretifolium* and *T. mengesii* were involved, i.e., in connection with twelve stations. Since no decision could be made for want of material in two instances (Bryant, DeKalb Co., & Cheawhaw Mt., Cleburn Co.), there remain ten stations representing as many counties from which *Talinum mengesii* is definitely known. The stations and counties are:

Eight-Acre Rock, Tuscaloosa County.
Shades Mountain, Jefferson County.
Clear Creek Falls, Walker County.
Warnock Mountain, Blount County.
Eight-Mile Creek, Cullman County.
Georgia Mountain, Morgan County.
Menton, De Kalb County.
Gadsden, Etowah County.
Baldrock, near Almond, Randolph County.
Auburn, Lee County.

If *Talinum teretifolium* Pursh is to be retained on the list of Alabama plants, it cannot be done so for the present on positive evidence, but merely dubiously so on circumstantial ground, no evidence to the contrary having been presented in the two instances, cited above.

There remains one other station, Coosa River in Chilton County, which takes a position of its own. The discovery of *Talinum* there by Dr. R. M. Harper represents a new addition to the Alabama flora and, at the same time, to the Appalachian flora and the species is proposed here as:

**Talinum appalachianum** sp. nov.

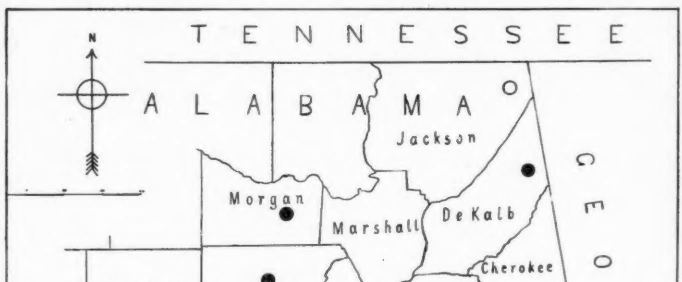
Planta parva, 0.7-1.8 dm., inclusive caulis et inflorescentiae; caulis perennis, altus 2-4.5 cm., paulo tenuis, erectus, ascendens aut basi decumbens; folia tereta in apice caulis vel ramulorum dense fasciculata; pediculus tenuis; cyma patenta; flores parvae, petala 3.5-5 mm. longa; stamina ordinarie 5 (vel 6-7) alternipetala (!); stylus obconicus 0.5-1 mm. longus exclusive stigmatis; stigma distincte tripartitum aut capitatum; capsula ovoidea 3-4 mm. longa; semina leviter badia.—Saxa denudata in commitato Chilton, Alabama. Typus Herbarium St. Bernard College, no. 4211.

All in all, thirteen stations are known: Ten stations of *Talinum mengesii;*

two stations for *Talinum teretifolium* Pursh; and only one station for *Talinum appalachianum*.

### Talinum mengesii Wolf

The close affinity of the two predominant Appalachian species, *Talinum teretifolium* and *T. mengesii*, indicates that both have evolved from some common ancestral form, presumably of Appalachian stock. By reason of intimate relationship it is to be assumed that development of these extant forms had proceeded undisturbed from foreign influx since the earliest permanent establishment of the respective presumable ancestor within the southern Appalachian Highlands. The original habitats of it were probably the barren granitic rock-formations of the mountainous ranges of said region which, at the same time, may be considered the center of diversification. It is likely, that during the early period following the establishment, and probably for some time after, Alabama may not have harbored any Talinum at all.



On this presumption, *Talinum mengesii* probably immigrated into Alabama, principally by way of Lookout Mountain. Although the trend of migration of the species is toward lower levels, at the present time this is for the most part ineffective in the more southern, lower situations, mainly by reason of occupied ground.

If at present the most flourishing center is located at higher elevations near the northeast corner of the State, this is not to be misinterpreted as an original migration from lower situations farther south, where it had been losing ground since unknown times. Rather, it might be compared with retracing steps, though in reality the similitude is amiss.

Granted that the species be an immigrant, it would be folly to suppose that it had immigrated in those recent times, when already a formidable flora had taken possession of the extensive table lands, which stretch south toward the center of the State. The capacity of the species is not of the nature of a straggling vagrant, establishing temporary quarters here and there, wherever a suitable spot is found. On the contrary, the keynote is permanency of establishment in connection with a most primitive environment. The species is a harbinger, a precursor. Time, and more time, is an important factor in both directions, colonization as well as surrender of habitat. Provided excellent drainage, a century is not sufficient under otherwise most disadvantageous surroundings—for instance, a narrow strip measured by a few score of yards in width, and completely hemmed in since unknown times by extensive, practically uninterrupted, regional forest land, with progressive marginal as well as internal encroachments constantly at work.

It may reasonably be assumed, that immigration of the species took place at such an age, when a most primitive environment was a universal feature. If so, the peneplain of the southmost extremity of the Appalachian Plateau offered ideal environmental conditions for permanent establishment and, furthermore, for progressive spread in its southward advance toward the inland boundary of the present coastal plain, which seems to have marked the barrier against further progress. The vast expanse of barren sandstone of the Pottsville formation possessed also this one essential feature, good drainage, a paramount requisite for long-term occupation of invaded territory. This aided, likewise, seed dispersal which, however, is not identical with rapid population of local colonies. The species is not a pocket-plant, neither a crevice plant. Its immediate substratum is the horizontal or inclined rock surface and, thus individual establishment depends on a combination of favorable factors. This accounts for the loose association of individual plants, which is maintained only by excellent drainage on a broad scale. The loose association is and has been of immense benefit toward permanency of established colonies for indefinite periods of time, because, rapid invasion by foreign elements is favored to a high degree in well-stocked habitats long before the stage of saturation was reached. The action of said sort of drainage on the barren sandstone surface also adds (and has added) that minor ultimate contour-

detail, which constitutes a beneficial preparation in creating that waterworn, shallowly undulating rock surface, to which the plant is especially well adapted.

The regions of widest distribution of the plant are the table-lands south of the Tennessee Valley and the more narrow northeastward extension. There, conditions, as they indisputably existed at some bygone age, had been in absolute agreement with requirements pertaining to a pristine flora not materially different from that of primitive extant habitats. The conditions existing then are to be summed up thus: a vast expanse of soilless barren sandstone; exposure to open sunshine without obstruction other than temporary clouds; such moderate precipitation as chanced at intervals; good, and even excellent drainage, and a long space of time. This fulfilled all the requirements concerning a most favorable environment for the welfare and spread of the species, so that absolutely nothing was wanting. It need not be assumed that flourishing conditions of the respective pristine flora obtained alike over the extensive region at one and the same period of time; neither, that there existed uninterrupted continuity of habitat. But, it may reasonably be taken for granted that *Talinum mengesii* represented the predominant flowering species throughout the season of the year. Possibly, its chief and only really conspicuous associate had been *Cladonia rangiferina* (or related kind), and both plant types together may have dominated the physiognomy of the flora existing then.

Encroachments by elements of succeeding floras were bound to come, and inceptions may have taken place at an early period, probably long before distribution of Talinum had reached its maximum extent. Invasions depended on some improved environment with regard to soil. Although drainage on the whole had always been excellent, there must also have existed numerous spots dotting the vast expanse, where drainage had been less perfect. Here, first depositions of soil derived from erosion, prepared the ground for restricted local invasions by foreign elements on a gregarious basis. The immediate effect on the situation in general, however, could not but be of a rather negligible character, because, initial progress of extension of local areas was to proceed at a slow rate. But, in the end of a prolonged course of time, these and other modes of upland encroachments were of more serious consequences by far, than marginal and back-cut invasions. The natural sequence in course of events was to consist in the breaking up of more or less continuous region units into more localized smaller and smaller ones. In turn, through locally complete loss of ground, Talinum habitats became more and more widely separated from one another and, ultimately, remotely isolated. Driven from the uplands, chances for the establishment of refuge habitats lessened by and by, and were directed toward lower levels, relative to local elevations. Quite naturally, the situation was to reach sooner a precarious stage in sections with no marked topographical relief, and if there is one or other remaining-habitat still extant, it is along the course of a creek. There, comparatively recent rock-exposures were the result of narrowing and deepening of the drainage channel, and these rocky flats offered a last chance of refuge for at least some time to come.

The above statements refer to the region of the Appalachian Plateau, the territory of widest distribution of the species within the State. On the southeast it is adjoined by the Cahaba Ridges toward which the plant had also found its way, as is evidenced by the extant habitat on Shades Mountain. The Cahaba Ridges represent a subdivision of the Appalachian Valley in Alabama. Within this combined territory the sandstone of all the respective habitats (possibly with one exception) is of the Pottsville formation, which is the uppermost of Paleozoic rock formations as represented in Alabama. Two of all the known stations are located in limestone regions. In Morgan County the sandstone of the habitat is an outcrop, possibly of the Mississippian Series, but on Warnock Mountain in Blount County the habitat sandstone is of the normal capping, in accord with the overlying Pottsville of the adjacent region. The station of Eight-Acre Rock in Tuscaloosa County takes a unique position, being situated within the Cretaceous of the coastal plain near the arbitrary "Fall-line." Here, the sandstone is an outcrop of the Pottsville formation which dips gently, and directly goes underneath the Tuscaloosa formation of the Cretaceous system. With regard to the geographically distinct Piedmont section, it is probable that the species may have entered the State by a route of its own. Of the two definitely known stations, Baldrock near Almond in Randolph County is remarkable for the fact that *Talinum mengesii* is growing on granite rock (Harper). No information obtains about the Auburn station.

In its isolation within the State *Talinum mengesii* has maintained its uniform character to such a degree as to belong in the category of fixed species. Besides the similarity in habitat and vegetative structures (the rootstock varying from a somewhat elongated to a small knotty clump), anthological and carpological features hardly exhibit any variation. If examination of limited material from two southmost stations is conclusive, relative length between longest stamens and the style is not marked to such a strong degree as usually is the case. In reality, the difference rests merely with two opposite trifles whose combination affects appearance rather than essence. Anthers are always small, and the style always longer than the stamens, the stigma is either capitate or at least so in appearance, and the ovary and capsule are subglobose. The only obvious tendency is the one toward petalomany by way of stamen-transformation, which seems to be a universal characteristic within the State—the number of petals ranging from five to ten.

Phylogenetically, *Talinum mengesii* is unmistakably an Appalachian product, and not a basic Appalachian species. The high degree of stability together with the particular combination of anthological features—purposeless in the absence of an alternative counterpart—indicates, that the species represents a selective form, which chanced to have become differentiated in the course of phylogenetic rearrangements incident to dissociation of factors, originally combined in a more complex ancestor of whatever type this may have been. This opinion had been entertained by the writer for some time, and from it had emanated as a mere natural consequence, the question concerning a presumable ancestor. For this question, however, no satisfactory

answer had been close at hand. Only two Appalachian species had ever been proposed. Their intimate affinity is obvious enough, and if the ancestor-question were to hinge on these two species, then *Talinum teretifolium* is to be considered as far better qualified to figure as the supposed ancestor of *T. mengesii,* than vice versa. But, the writer could never seriously consider the mentioned fact a plausible solution. It appeared to him more likely, that both species had originated on Appalachian soil from a common ancestor. With no such extant form at disposal, he rather has chosen to consider the matter of origin an unsolved problem, with no prospect of a plausible solution in view.

### TALINUM APPALACHIANUM sp. nov.

In early May, 1937 Dr. R. M. Harper advised an investigation of a Talinum he had then discovered on granitic rock in Chilton County, while exploring on other lines. This had to be postponed for reasons of health, but in August material was procured from the respective locality (coll. M. Morgan and M. Mages). The diagnosis could be summed up thus:

The low aerial and basifixed stem erect, ascending, or decumbent at the base, simple or subsimple, 2-4.5 cm. high: leaves terete, more or less subulate, approximate in a dense tuft at the apex of the stem, sometimes also a tuft terminating a lateral ramulus or two subterminal forking ramuli each; slender primary peduncle terminal, lateral ones from the axils of the leaves; cyme open; flowers small; sepals ovate to orbicular-ovate, 1-2 mm. long; petals five, obovate, 3.5-5 mm. long; stamens normally five and alternipetalous (!), or 6-7, with the supernumerary one, or ones, antipetalous; ovary ovoid, 1.5 mm. long; style proper obconical, 1 mm. or less long, stigma 0.5 mm. long, distinctly tripartite (refers to the then examined material); capsule ovoid, 3 or hardly 4 mm. long; seeds brown, smooth, about 0.9 mm. wide.

Apparently, the plant from Chilton County was to represent the eastern counterpart of *Talinum parviflorum* Torr., and seemed to offer no further prospect of particular interest. But, on closer attention, the straight pseudomonopodium excited more careful scrutiny. Though this is a striking and almost universal feature of the plant material, certain indications led to the assumption that the plant might be of a plastic type, whose simplicity was merely masking the undeveloped, but genetically fundamental habit of dichotomous ramification. The apparent monopodium seemed to represent merely a form of adoption for the sake of economy, the supression of axial growth enabling the plant to endure the severity of a most primitive environment. If so, soil-environment was apparently to be considered the principal balancing factor in either direction.

In order to test the correctness of this interpretation, almost all the material was then potted. Such activities as may be expected at so late a period of the season were resumed rather immediately. It thus became evident that three different sizes of anthers are involved with different flowers, without,

however, any indication of particular correlation. Some pseudocleistogamy occurred toward the end of the season. There was also some lengthening of internodes, at least between the lower ones of the crowded leaves, but this became partly counteracted by contraction during the season of dormancy. Of particular interest and significance was the position of the developing buds, since they indicated what mode of development might be expected with the beginning of next year's season. The geminate subterminal winterbuds

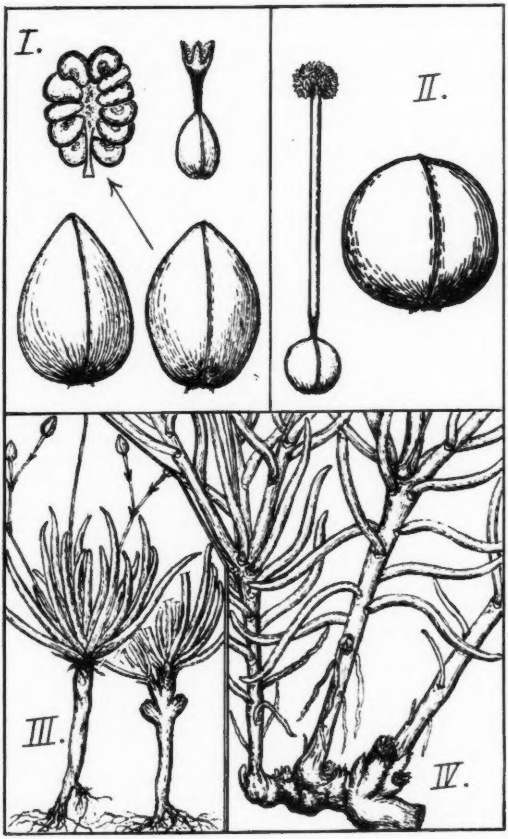



PLATE 1. Figs. I and III refer to *Talinum appalachianum;* II and IV to *T. mengesii.* Figs. I and II, x7.

developed to the size of about 3 mm., each bud of the pair opposite the other, and then remained dormant until spring. So far, the prospect appeared to be a favorable one, and if dichotomous ramification could actually be demonstrated as the norm of branching, a speculative mind might be tempted to draw conclusions in the direction of descent from an opposite-leaved progenitor. On the other hand, the tendency toward suppression could also be discerned by the fact that in a number of instances one bud of the pair exhibited lesser vitality than the opposite one.

During the following season 1938, all extra stimulations were avoided, the potted plants receiving only a sprinkling of water at irregular intervals, and soil conditions were not of the best. A survey at the end of the season of this year, with dormant winter-buds formed, yielded a convincing manifestation of what had originally been expected on somewhat theoretical ground. Not only had dichotomous ramification asserted itself as an established fact by this season's mode of actual branching, but there had also been assured the repetition of said kind of ramification for the next season in consequence of the geminate subterminal position of winterbuds. Figures 6 and 7 (Plate 2) represent diagrammatic illustrations of two plants at the end of the season of 1938. Size and position agree with those of the respective plant, and the short lines at the base of each respective fork indicate the scales (segmenta foliosa) of the bud which had been formed about the end of the previous season (X indicates a succumbed ramulus).

Here, the writer must apologize to the reader for the introduction of matters not exactly consistent with the nature and intended scope of this article. When in 1937 the above mentioned indications developed, the question concerning the ancestry of Appalachian Talinums could not then be disregarded altogether as a personal matter. Thus, an inquiry into the minutiae-complex with regard to extant Appalachian forms became of tempting interest. This would require a long-drawn search for data as complete as could possibly be obtained. Increasing infirmity, however, prevented further investigation. It is also for this same reason, that comparative matter and fragmentary details are here prematurely published. If *Talinum mengesii* has the distinction of being the predominant species in Alabama, Dr. Harper's discovery of *T. appalachianum* seems to be of more far reaching importance, because, it may offer a key for the better understanding of the Appalachian situation on phylogenetic grounds.

Dichotomous branching as an established fact serves a good purpose for evaluating the degree of vegetative affinity, that obtains among the three proposed Appalachian species. Thus, with regard to axial growth, the affinity between *Talinum mengesii* and *T. appalachianum* is to be considered a remote one, too remote to allow for a satisfactory demonstration of direct connection in this respect. *T. mengesii,* so far as learned by the writer, is a perennial herb in the strictest sense, and nothing else. It is altogether different with *Talinum teretifolium*. This species takes an intermedaite position and its direct connection with *T. appalachianum* on ground of axial growth can be satisfactorily demonstrated. But, for the reason that at least one ecological

factor is involved in the expression of the respective phenotypes, not every one of the field or herbarium specimens serves the purpose equally well—some are unfavorable objects, others suitable in varying degree, others are excellent. Of the latter category there is a specimen of *T. teretifolium* at the Herbarium of the Academy of Nat. Sciences of Philadelphia, no. 7625, collected by F. W. Pennell & Bayard Long in Westchester County, Pa., which is not to pass unmentioned. It is not only an admirably perfect herbarium specimen as such, but is, at the same time, a very instructive one. In fact, it represents a classic example of serially adaptive form in response to

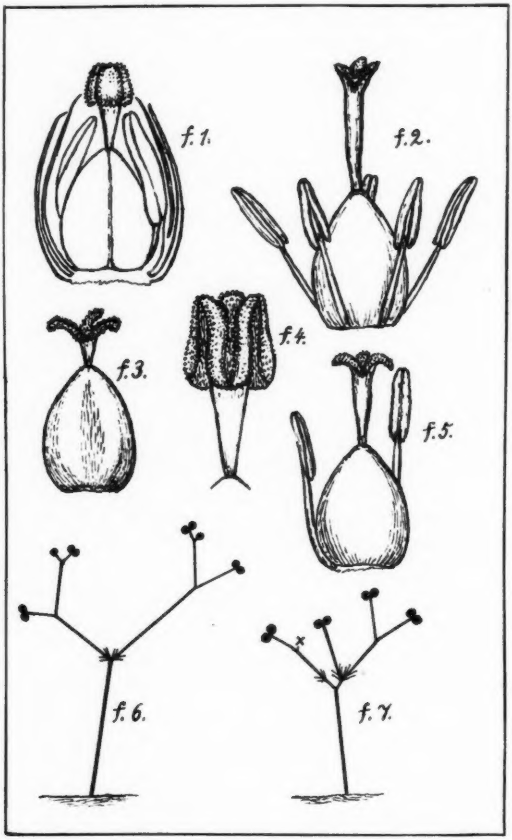



PLATE 2. Figs. 1-3, 5-7, x14. Fig. 4, x30.

altered environment, here exhibited by one and the same plant. The three principal phases are structurally expressed with such distinctness and clarity, as to exclude any confusion. Two phases cover the characteristic features of *T. appalachianum*, the third phase represents an advanced plant type. Thus, there is:

1. The phase relative to most severely primitive environment—its mode of adaptation expressed by the basifixed pseudomonopodium of perennial duration. This compares well with the monopodial character of field material of *T. appalachianum*. (The blunt base likewise is a characteristic feature of the latter species, but not of the two figures of Pl. 1).

2. Higher up (between 3 and 4 cm. from the base) begins the phase relative to tolerably improved soil-environment—its effect structurally expressed by dichotomous ramification, likewise perennial duration. This coincides with the experimentally established mode of ramification in case of *T. appalachianum,* when grown in soil instead of on rock. (In the respective herbarium specimen the inner branch of the right secondary fork crosses underneath the inner branch of the left secondary fork).

Next higher up follows the transition into quite a different plant type:

3. The phase relative to markedly improved soil environment—the phenotypical expression being the perennial herb in the strict sense which, in said specimen, is developed to the highest degree of perfection.

Thus, the affinity of *T. teretifolium* with both other Appalachian species becomes obvious. With regard to phases 1 and 2 *T. teretifolium* belongs in one and the same category with *T. appalachianum,* while with regard to phase 3 it belongs in the category reprsented by *T. mengesii.* In the two species *T. teretifolium* and *T. mengesii,* the tendency toward trichotomous subterminal forking of the induviate herbaceous shoots is a strongly marked feature which may be repeated in secondary, etc., forkings.

Concerning anthological features, by far too little is known. The insignificantly small flowers of rather monotonous uniformity seem to offer little of particular interest, at least on casual observation. Truly, interesting details are but tardily revealed. So much, however, has become evident that, what might be considered the extant remnant of an ancient Appalachian species, represents a degenerated form, the original pattern of which cannot be safely reconstructed by imagination on the basis of such data as are at hand, and which are altogether insufficient. Thus, further investigation is needed since the condition seems to be a chaotic one. Such meager data as came to light do not reveal correlations, such as must have prevailed originally in the apparently more or less complex ancestral form. Even if there be one or another apparently correlated instance, assurance as to original combination can hardly be based on mere isolated facts. The material at disposal must be considered an heterogeneous assembly and partly at least, of heterozygous individuals.

As is the case with all Appalachian species, anthesis in *T. appalachianum*

is time-limited, and the period involved is a short one in contrast with the other two species. Even if time-limitation is indicative of genetic constitution, it would be rash to exclude or disregard phototropism and thermotropism altogether as factors involved, notwithstanding the fact that flowers of *T. mengesii* had perfectly opened in the dark of the vasculum, etc.,—in one instance at 11 a.m.,—it appears, however, as if thermotropism were the more influential modifying factor. Grown side by side, time-limitation in case of *T. mengesii* extended normally from 11 a.m. to 5 p.m., fluctuations being allowed up to 60 minutes within the limit for different days and different flowers. Abnormally, on some cool days in fall a complete shift of the period occurred, extending from 12 noon, or even 12:30 p.m. to about 6 p.m. All in all this seems to be in fair agreement with flowering periods in native habitats. On the other hand, the flowers of *T. appalachianum,* receiving sunlight somewhat earlier than those of the other species, always opened between 3 and 4 p.m., and closed between 5 and 6 p.m., the minimum limit hardly exceeding one hour.

The Stigma: This structure deserves special discussion in connection with all three Appalachian species. It also serves as an indicator of degree of affinity. Among the three species *T. mengesii* is the one that exhibits a fair degree of constancy in the form of stigma, which is rather consistent with the character of a supposedly extracted species. Here, the stigma is either actually capitate, or at least so in appearance; in the latter instance the short lobes are erect in anthesis, but usually slightly gaping. In *T. teretifolium* a rather unbalanced situation exists, and this for no obvious reason of correlation, which fact is phylogenetically significant. The diversity in form of stigma is the cause of some puzzling incongruity in taxonomic literature. Thus, for instance, A. Gray (2) implicitly describes the stigma as "three lobed" and this is to be understood without restrictive qualification because the explicit figure 3 of plate 98 allows for no diminution, (1848). Gray's New Manual (5) had the modified description "lobes of the stigma very short" (1908). P. Wilson (7) refers to the stigma as "capitate" (1932). This may have the appearance of a sort of chronological evolution. The truth, however, is that any of the cited statements is correct. Only, none is comprehensive enough to state the whole truth. The rather wide range of variation obtains even among individuals of one and the same locality. The purposeless diversity can only be explained on phylogenetic grounds and points in the direction of a more complex ancestor, whose harmoniously correlated pattern served definite purposes. Now in the third species, *T. appalachianum,* a similar wide range in stigma form obtains, indicating a close affinity in this respect with *T. teretifolium,* and a more remote one with *T. mengesii.*

Modification of Stigma: The principle is a simple one, the stigmatose surface always corresponding to the inner face of style members, the modifying factors involved being the degree of union of the lobes, and recurvation of lateral and apical margin of lobe. The simplest and unmodified form is the distinctly three-lobed stigma with flat lobes which, however, is not the most common form. Figure 4 (Plate 2) represents a stigma of *T. appalachianum*

with only the lateral margins strongly recurved. In this simplicity it is of rare occurrence, because, the recurved margin is usually continuous around the sinus and there semicircular or subcordate in outline even if the apical margin is barely affected. The recurved sinus margin exerts a strong effect on the appearance of the stigma. The accompanying shortening of lobes and apical recurvation in varying degree creates subcapitate and capitate stigmas; some thickening of apices may also be present. In capitate stigmas the lower edge corresponds for the most part to the apical margins, the presence of sinus margins being more or less obscured by some plication and by a marked development of marginal papillae. This mode of transformation applies to all Appalachian species alike.

Irregular Features: There are sufficient structural differences among flowers of *T. appalachianum* which allow for a fairly wide range of different combinations. That there prevails no harmonious order indicates clearly that we are dealing here with a degenerated species of random combinations. The variation in number of stamens is but slight, only once has there been encountered a flower with seven stamens. There is a difference in length of filaments, also in the size of anthers, which range from less than 0.9 mm., 1-1.1 mm. up to 1.3-1.4 mm., respectively; again, we find short styles, 0.5 mm. (with stigma about 1 mm.,) and long styles 1 mm., (with stigma about 1.5 mm.,), which, however, is not a clean-cut feature, intermediate lengths being frequent; differences in stigma have already been pointed out.

Owing to the small size of the flowers and the comparatively large stigma, autogamy in closing of flowers, even if insect pollination fails, is hardly prevented on account of the above mentioned structural differences. About the same measurements obtain with regard to the three different sizes of anthers in *T. teretifolium,* but middle-size anthers are by far more common, small ones apparently rare, and large ones more frequent in local regions. In *T. mengesii* the anthers are always of the small size and more plump or even roundish. This establishes another point with regard to close versus remote affinity.

A few isolated facts should still be recorded. For instance, one is represented by Fig. 2 (Plate 2), a fine example of relative length between androecium and gynaecium, but whose serious defect is its single occurrence and the absence of its alternative counterpart. Fig. 5 represents an abnormal case of an otherwise somewhat similar nature, three of the five stamens being shorter than the rest and stigma lobes widely spreading, which is of rare occurrence. Mentioned should be also several instances of a kind of proterogyny among vernal flowers, but whether these were originally obligate or not, is difficult to judge. Fig. 1 shows a specimen whose characteristic features are short style, capitate stigma, large anthers, and part of the stigma being exposed beyond the incompletely grown petals. But there were others of the kind with anthers of medium size and the stigma less distinctly capitate, or with short spreading lobes, thus exposing the stigmatose surface. Time of exposure varied rather considerably, which is consistent with the fact that the period

of anthesis is a fixed one, whereas development of flower buds proceeds independently of it. The maximum of exposure is approimaxtely 30 hours. On the day of anthesis the petals resumed growth again, and at late morning or early forenoon were tightly imbricated over the top of the stigma. In all instances the style was short. Fig. 3 represents a unique case of apparent proterogyny if not a genuine one. The stigma lobes were slender and the style almost obsolete. It had attracted attention by the exposure of the tips of the stigma members by way of gaping lateral margins of otherwise closed petals.

With regard to fruit, the subglobose capsule of *T. mengesii* is a constant feature, a slight difference between vertical and horizontal diameters in either way being within the limits of the term. The capsule of *T. appalachianum* is ovoid, whose constancy is unknown at present. The subglobose capsule of *T. teretifolium* is not absolutely constant, because, again and again, there crops out what might be considered an ancient trait in the form of elongated fruits in indvidual plants, sometimes both kinds of ovaries and fruits appearing on the same plant.

## Appendix

*Talinum mengesii* possesses certain horticultural qualities. Growing on rocks in its native habitat, its use for adornment of rockeries needs no comment. It is a neat and attractive small pot plant. Its ease of growing, independence of further attention than planting and sprinkling, its ready propagation by cuttings without the precautions usually involved, its great resistence against the hot rays of the sun and drying winds, etc., render the species eligible for such sunny windows as are otherwise too draughty for the well-being of most other plants. Cuttings are merely placed in sand, covered with sufficient water to last for the whole day before being replenished, and no covering against drying-out, nor shading against the rays of sun is required in the most sunny and draughty location.

For planting, low bowlshaped pots are preferable to narrow ones, as these can be stacked with more plants for a showy display. If about five inches high, almost half the depth should be filled with pebbles, overlaid with sphagnum moss, as the plants require no deep soil. Upon this matrix of sphagnum the soil is placed and the rootstocks, or rooted slips, are planted. A top-layer of sphagnum is beneficial in preventing surface crust of soil, etc. Even if the flowers are ephemeral, as soon as secondary, etc., cymes have developed in well-stocked plantings, a good number of daily flowers is rarely wanting.

A still more attractive curiosity display is effected by the use of a ten inch earthen saucer instead of a pot, as may be illustrated by the following experience. Talinum plants once were brought from a particular locality. Desiring to keep them growing for temporary observations, nothing but such a saucer was momentarily available at the third floor of the building. Some small pebbles and soil from a window flower box were carelessly thrown in, so as to keep the plants in place for the time being. When my observations were completed, the plants in full bloom represented such a neat display that they were left to shift for themselves—except for an occasional sprinkling during the rest of the season. Then they were placed at the corner of said flower-box, but were thereafter forgotten. At this high elevation the plant sin the dormant stage were freely exposed to the rigors of a rather severe winter—fierce winds, rain, sleet, snow, ice, alternately. At the time of replanting next spring, the saucer turned up again unexpectedly, the plants non-the-worse from the exposure. Their prolific sprouts from the rootstocks were proof of that fact. So, without replenishing the soil and with no other attention than sprinkling, they were kept for another season. On account of scant

soil and lack of attendance, the shoots remained somewhat shorter than usual, which, however, enhanced the beauty of their appearance. When flowering was well advanced, the neat and curious display was a most perfect one. Daily throughout the remainder of the season, there were from thirty to fifty purple flowers with numerous golden anthers swaying well above a beautiful green carpet of small dimension, the flowers measuring from three-fourths to nearly one inch in width.

As a mere oddity, the plant can also be grown as a kind of an aquatic in more or less flat-bottomed bowls, deep pans, etc. A layer of clean sand about one and a fourth, to one and a half inch deep suffices, covered by one inch of water to be replenished as the water-level sinks. In a long course of time, siphoning off of the old water at more or less long intervals is advisable. If cuttings are used for stocking, they ought to be placed not more than two inches apart and, preferably, prerooted, thought the slips can be rooted in their ultimate place and then be left in situ. Flowers will not be so prolific as when the plants are grown in soil, but they are large, measuring fully one inch or somewhat more.

No universally applied common name can be expected in the case of a species which is known only to few people on account of its widely separated and secluded, or out of the way habitats. So far the writer has learned of the application of a common name only in connection with a single locality not in Cullman County, where he resides, but in adjacent Blount County. There the Warnock Mountain habitat is in close proximity with mountain dwellings, and it is there that *Talinum mengesii* is definitely known as "Rock-Moss."

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## REFERENCES

1. Butts, C. 1926—The Paleozoic Rocks. Geology of Alabama: 40-230.
2. Gray, A. 1848—Genera Florae Boreali-orientalis **1**:225; pl. 98.
3. Harbison, F. G. 1902—A Sketch of the Sand Mountain Flora. Biltmore Bot. Studies **1**:151-157.
4. Mohr, C. 1901—Plant Life of Alabama. Contrib. U. S. Natl. Herb. **6**.
5. Robinson, B. L. and M. L. Fernald. 1908—Gray's New Manual, p. 388.
6. Small, J. K. 1933—Manual of the Southeastern Flora, p. 494.
7. Wilson, P. 1932—North American Flora **21**(4):289.
8. Wolf, W. 1920—Notes on Alabama Plants. Amer. Midl. Nat. **6**:151-155.

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# Edapho-Vegetational Relations in Ravenel's Woods,

## A Virgin Hemlock Forest near Highlands, North Carolina

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Within the last few years, it has become evident to American forest ecologists that if the true natures of the forest climaxes of the eastern part of the North American continent are to be fully understood, thorough studies must be made of the scattered remnants of virgin forest which once covered this wide area. Through agriculture, lumbering, fire, and grazing, this original forest has been decimated until only a few scattered tracts of relatively undisturbed woodland remain. These are gradually disappearing year by year. Before this remainder has entirely disappeared or has been substantially altered, it is highly desirable that the vegetational and edaphic features of the several climaxes represented be worked out as thoroughly as possible.

Detailed studies of the vegetational nature and structure of virgin forests have been published by Nichols (1913), Lutz (1930, 1930a, 1934), Cain (1931, 1934, 1935), Potzger and Friesner (1934), Hough (1936), Morey (1936, 1936a), Daubenmire (1936), Aikman and Smelser (1938), and Eggler (1938). The papers of Lutz, Hough, and Morey are statistical studies of the vegetation of coniferous virgin forests in northwestern Pennsylvania and constitute a valuable collection of information on the vegetational relations of such forests in that region. Studies on similar virgin forests in the Southern states are lacking. It is the object of this paper to present the vegetational structure and certain of the edaphic conditions in a virgin hemlock *(Tsuga canadensis)* forest in the southern Appalachian Mountains.

The forest of this investigation is Ravenel's Woods, also known as the Primeval Forest, near Highlands, Macon County, North Carolina. The tract has been owned by the Ravenel family of Charleston, South Carolina for many years and is now owned by Mr. S. Prioleau Ravenel. Lying at an altitude of about 4,400 feet, the area is approximately 4 miles east of Highlands and 3 miles to the west of the summit of Whitesides Mountain.

Although the Ravenel holdings are not entirely of virgin timber, they include an area roughly 1½ miles by 1 mile in extent which has not been burned, grazed, or cut in any way except that an occasional fallen tree trunk has been cut in two when it lay across the single narrow trail. According to the Ravenel caretaker, some lumbering was done twenty or thirty years ago to the north of the present virgin tract. The lumbered area surrounds the old sawmill pond and is now grown up thickly with blackberries, rhododendron, and second-growth timber. To the west of the undisturbed area, there has also been some cutting. The virgin forest occupies roughly a triangular area between these lumbered portions and a spur of Whitesides Mountain.

Although surrounded by mountainous territory with abrupt changes in altitude, the general topography of the forest area is gently rolling. It is traversed by two or three small streams which have cut distinct, but not deep, valleys as they flow toward a larger stream along the western edge of the forest.

The climate of the region is very moist, the average yearly rainfall at Highlands, four miles to the west, being over 80 inches. This abundance of rainfall is reflected in the vegetation which is very luxuriant. With a mean temperature of 39.7 degrees in January and 70.4 degrees in July, Highlands vicinity has a rather equitable climate, typical of regions several hundred miles to the north except for the high precipitation.

From nearby elevations, the general aspect of the forest is that of a continuous hemlock stand which, because of its dark green color, contrasts strongly with the surrounding vegetation. Inside the forest, the impression is of many size classes of trees dominated by the scattered hemlocks which are very large. Here and there throughout the forest are standing or recently-fallen dead trees. A hemlock which had fallen across the trail had been sawed in two by the caretaker. Of typical size, it was found to have 450 rings about 12 feet above its base. Many of these large hemlocks have evidently been killed by lightning, while others, having passed maturity, are the victims of fungi. The dead trees are sooner or later blown down by the wind, leaving openings in the crown canopy. Under these openings and occasionally along the trail, appear species which are obviously not a part of the climax vegetation. These species are typified by *Rubus canadensis*[1] which, in certain parts of the forest, forms impenetrable tangles in the openings.

## Methods

After a reconaissance, it was seen that the forest is made up of two distinct types based upon the shrubby and secondary tree synusiae and upon topographic position. Along the streams and in the depressions, *Rhododendron maximum* is the principal secondary tree and shrub, almost to the exclusion of other species. In places, the Rhododendron layer is so dense and tangled as to be practically impenetrable. Along the ridge tops and the rather level interstream areas, Rhododendron is generally absent. Here, *Polycodium stamineum* (L.) Greene forms a low shrub synusia which is in striking contrast to that of Rhododendron. The overstory of both sites is hemlock.

Because of this obvious difference in subordinate species, the two types were handled separately when sampling the vegetation and soils. For the sampling procedure, the forest was divided roughly into three divisions: two consisting of portions in which Rhododendron was predominant, and the other, the largest single expanse in which the Polycodium synusia was present. In each division, a series of ten sets of quadrats was laid out. The number

1 Nomenclature of flowering plants is that of Gray's Manual, 7th ed., unless authorities are given.

of sets was found to be entirely adequate because the species-area curve (after Cain, 1938) for every synusia levelled-off between the sixth and ninth sets of each series. By means of a compass and steel tape, the sets were spaced as evenly as possible throughout the forest divisions, in two rows, with intervals of twenty meters between sets. Each set consisted of a nest of three quadrats, the largest size being ten by ten meters on a side, with the smaller sizes (two by two and one square meter) superimposed in one corner. On the largest size of plot, counts and diameters were obtained for all of the woody individuals over one inch d.b.h.[2] Records for overstory and understory were kept separately. Shrubs and woody reproduction under one inch d.b.h. were counted on the two by two plots while the herbaceous species were listed and their coverage estimated on the smallest plots. The shrubs and woody reproduction under one inch d.b.h. were further subdivided into those below and above one foot in height. From these data, it was possible to determine the density and frequency of all of the woody species in the respective forest divisions and synusiae as well as the basal area of the species making up the dominant and secondary tree layers. The frequency and average coverage of the herbaceous plants were also determined.

Soil samples were collected in two sets of ten each, from each of the three divisions of the forest. Nine samples in each set were collected in the form of a latin square having intervals of one meter between samples. The tenth sample was collected one meter from the middle sample on one side of the square. Samples were taken in undisturbed condition from the surface soil in metal cans having a volume of 234 cubic centimeters. The organic horizons on the surface (about two inches thick) were scraped away until the first mineral soil was exposed. The inverted can was carefully pushed into the soil until the bottom was even with the soil-surface, after which it was carefully dug up and covered with a tight lid. Several preliminary attempts showed that the cans were completely filled with soil in a practically undisturbed state. In the laboratory, the lids of the sample-filled cans were replaced with tight-fitting screens lined with filter paper. Thus enclosed, the samples were immersed in water for twenty-four hours, taken out, weighed immediately, drained for twenty minutes, and reweighed. After drying in an oven at 105 degrees Centigrade for forty-eight hours, they were weighed again. These weighings permitted calculation of water-holding capacity in percentage of volume of the sample, volume-weight, and air capacity.

The percentage of organic matter in the soil was determined by the loss-on-ignition method using a portion from each of the field samples. Hydrogen-ion concentrations were determined with a glass electrode and a Beckman pH meter. Four grams of soil from each sample were stirred in 40 milliliters of distilled water and determinations of the pH of the mixtures were made after they had stood overnight.

Observations were made of the depth and character of the organic horizons

2 d.b.h.—diameter breast high.

in both the Rhododendron and the Polycodium types of forest. Also, borings were taken with a soil auger at various places throughout both types to ascertain the thicknesses and textures of the mineral soil horizons.

## Results

### a. VEGETATION

In Figure 1, following the method of Lutz (1930), appear phytographs of the dominant tree species of both the Rhododendron and the Polycodium types of hemlock forest. Four dominant species of trees appeared in the 1,000 square meters sampled from the Polycodium type, namely *Betula lenta, Castanea dentata, Quercus borealis* Michx. f. (including its variety *maxima*), and *Tsuga canadensis*. Of these, from the standpoint of abundance, frequency, number of size classes represented, and basal area of the dominant individuals, *Tsuga canadensis* is clearly the most important. In twenty sample plots totaling 2,000 square meters in the Rhododendron type, six species of dominants were encountered. These were *Acer rubrum, Betula lenta, Castanea dentata, Halesia carolina, Liriodendron tulipifera,* and *Tsuga canadensis*. On the same bases as in the Polycodium series, *Tsuga canadensis* is proportionally even more important in the Rhododendron type. The average number of dominant hemlocks (density) per 100 square meters is 1.8 in the Rhododendron type compared to a density for the same species of only 0.8 in the Polycodium type. The average basal area of dominant hemlocks per 100 square meters is 4.147 square feet in the Polycodium type and 7.835, or almost twice as much, in the Rhodendron type. As regards total basal area of all dominants, the average figure per 100 square meters is 10.601 square feet in the Rhododendron type compared to 8.102 square feet in the Polycodium type.

Phytographs for the secondary trees, those trees over one inch d.b.h. and clearly not of the dominant stratum, are shown in Figures 2 and 3. The most important secondary trees in the Polycodium type appear to be *Halesia carolina*, a characteristic member of this synusia, and the transgressive representatives of the dominant *Tsuga canadensis*. As would be expected, *Rhododendron maximum* is by far the most important tree in this stratum in its own characteristic type. It is dominant in the understory, as shown in Figure 4, almost to the exclusion of other species but it is followed in importance by *Kalmia latifolia, Halesia carolina,* and the transgressives of *Tsuga canadensis*, the latter being much more poorly developed than in the Polycodium type. The basal area of the secondary trees is also greater in the Rhododendron type, averaging 1.120 square feet per 100 square meters contrasted to an average of 0.818 square feet for the same area in the Polycodium type.

In Tables 1 and 2, appear frequency and density data for all woody plants under one inch d.b.h. occurring in the two types. As regards the transgressives in this stratum of the Polycodium type, *Acer rubrum, Betula lenta,* and *Tsuga canadensis* are the most important, although no examples of the latter species

Abbreviations used in phytographs: S—standard, AL—*Amelanchier laevis*, AR—*Acer rubrum*, BL—*Betula lenta*, CD—*Castanea dentata*, FP—*Fraxinus pennsylvanica* var. *lanceolata*, HC—*Halesia carolina*, HV—*Hamamelis virginiana*, IM—*Ilex monticola*, KL—*Kalmia latifolia*, LT—*Liriodendron tulipifera*, MA—*Magnolia acuminata*, MF—*Magnolia Fraseri*, PP—*Pyrularia pubera*, PS—*Prunus serotina*, QB—*Quercus borealis* and var. *maxima*, RM—*Rhododendron maximum*, TC—*Tsuga canadensis*, V—*Vaccinium* sp., VN—*Viburnum nudum* var. *angustifolium*.

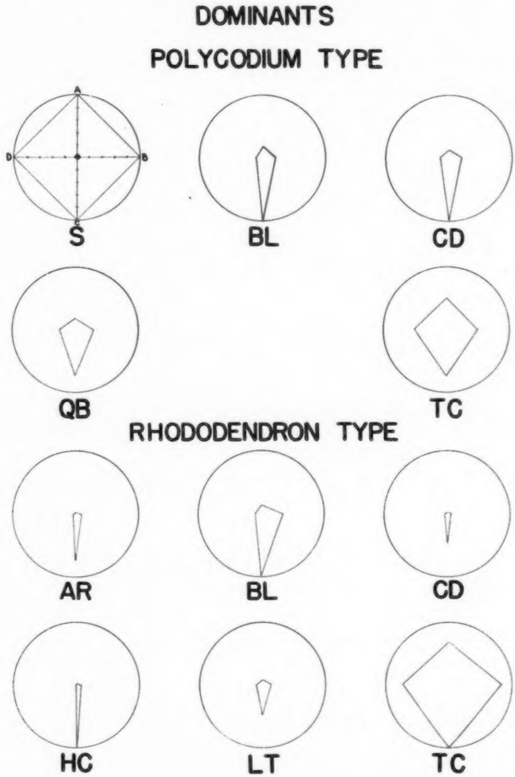


Fig. 1. Phytographs for the dominant tree species of both the Rhododendron and the Polycodium types. Radius A-O—percentage of total dominant abundance; radius B-O—percentage frequency; radius C-O—percentage of total size classes represented; radius D-O—percentage of total dominant basal area. Phytographs for Rhododendron type based on data from twenty 10 x 10 meter plots; those for Polycodium type on data from ten 10 x 10 meter plots. The phytograph for Tsuga in the Polycodium type shows only three of the four size classes as represented since no example of this species over one foot in height and under one inch in diameter appeared on the plots from which these graphs were constructed. However, occasional individuals of this size were seen off the plots.

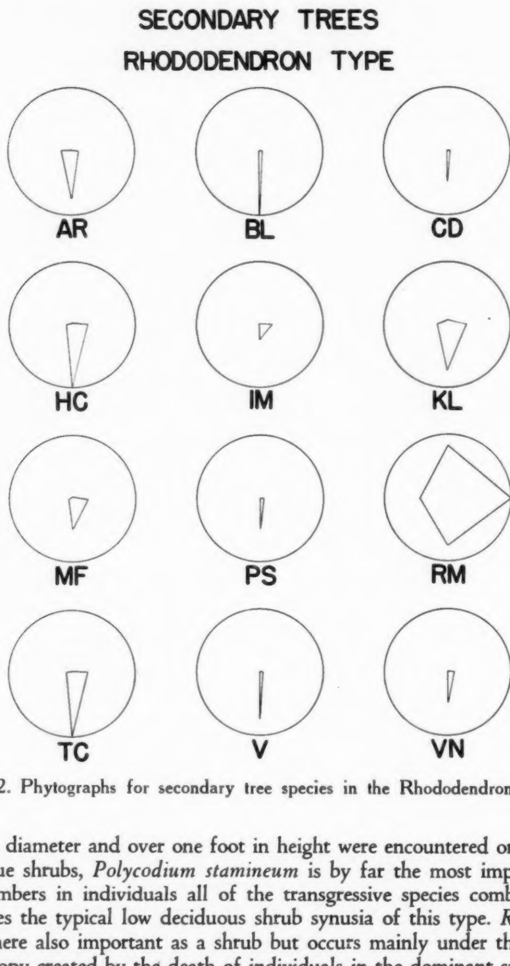


Fig. 2. Phytographs for secondary tree species in the Rhododendron type.

under this diameter and over one foot in height were encountered on the plots. Of the true shrubs, *Polycodium stamineum* is by far the most important and far outnumbers in individuals all of the transgressive species combined. Fig. 5 illustrates the typical low deciduous shrub synusia of this type. *Rubus canadensis* is here also important as a shrub but occurs mainly under the openings in the canopy created by the death of individuals in the dominant synusia. Of the transgressive species in the shrub synusia of the Rhododendron type, *Tsuga canadensis* and *Betula lenta* are the best-represented of the dominant species, while *Rhododendron maximum, Kalmia latifolia,* and *Halesia carolina* are the most numerous and widely distributed of the typical secondary trees. The true shrubs are poorly represented in this type but their places are taken by the seedlings and canes of Rhododendron which are of shrubby form but which

may continue to grow and become part of the secondary tree synusia. The importance of Rhododendron in this type is thus further shown by its domination of the shrub stratum as well as of the secondary arborescent layer.

The coverage and frequency of the herbaceous vegetation of both the Polycodium and the Rhododendron types appear in Table 3. As can be seen, herbaceous growth under the dense cover of the Rhododendrons is very scanty. *Mitchella repens* and *Galax aphylla* are the only flowering plants which appear on the twenty plots in this type. They are exceeded, in both degree of distribution and amount of ground covered, by the combined mosses and liverworts. Only 12 per cent of the ground in the Rhododendron type is covered by the herbaceous synusia. On the other hand, in the Polycodium type, the herbaceous synusia covers approximately 57 per cent of the ground. Undoubtedly, much of this difference is caused by the greater amount of light reaching the forest floor in the latter type. Another factor restricting the growth of herbs in the Rhododendron type may be the high organic content of the surface soil. Of course, this again is probably related to the dense shade cast by the broad sclerophyllous leaves of Rhododendron and the resulting effects


Fig. 3. Phytographs for secondary tree species in the Polycodium type.

Fig. 4. Typical aspect of the virgin hemlock community in the Rhododendron type. Note the almost complete dominance of the evergreen *Rhododendron maximum* in the secondary tree synusia.

Fig. 5. Characteristic appearance of the Polycodium type of virgin hemlock forest. Note the rather uniform height of the low Polycodium synusia. The large-leaved understory tree at the left is *Magnolia Fraseri*.

upon oxidation of organic matter through temperature and humidity control. The most important herb in the Polycodium type is *Mitchella repens* which exhibited 100 percent frequency in the plots and covers 27 percent of the total forest floor in the type. This species is followed in importance by *Viola rotundifolia, Dryopteris intermedia,*[3] *Dryopteris noveboracensis, Dennstaedtia punctilobula, Lycopodium lucidulum,* and *Medeola virginiana.* Altogether, there are 16 species of flowering plants and ferns making up the herbaceous synusia in the Polycodium type, a strikingly more luxuriant ground layer, both in coverage and number of species, than that under Rhododendron.

TABLE 1

Frequency and density of woody individuals under one inch d.b.h. in the Rhododendron facies. Based on twenty 2 x 2 meter plots.

| Species | Frequency over 1 ft. | Frequency under 1 ft. | Frequency all | Density over 1 ft. | Density under 1 ft. | Density all |
|---|---|---|---|---|---|---|
| Woody Reproduction | | | | | | |
| *Acer rubrum* | | 15 | 15 | | .6 | .6 |
| *Betula lenta* | 5 | 20 | 20 | .35 | 1.7 | 2.05 |
| *Clethra acuminata* | 5 | 5 | 5 | .1 | .05 | .15 |
| *Halesia carolina* | 5 | 25 | 30 | .1 | .3 | .4 |
| *Kalmia latifolia* | 20 | 20 | 25 | .4 | .45 | .85 |
| *Liriodendron tul.* | 5 | | 5 | .05 | | .05 |
| *Magnolia Fraseri* | | 5 | 5 | | .05 | .05 |
| *Prunus serotina* | 5 | | 5 | .05 | | .05 |
| *Rhododendron max.* (canes) | 70 | 30 | 75 | 4.65 | .9 | 5.55 |
| *Rhododendron max.* (seedlings) | 60 | 60 | 80 | 1.85 | 1.8 | 3.65 |
| *Rhododendron max.* (canes and seedlings) | 75 | 75 | 85 | 6.50 | 2.7 | 9.2 |
| *Tsuga canadensis* | 10 | 55 | 55 | .1 | 5.95 | 6.05 |
| *Vaccinium* sp. | 5 | | 5 | .15 | | .15 |
| *Viburnum nudum* var. *angustifolium* | | 5 | 5 | | .15 | .15 |
| Shrubs* | | | | | | |
| *Polycodium stamin.* | | 10 | 10 | | .1 | .1 |
| *Rubus canadensis* | | 10 | 10 | | .2 | .2 |
| *Smilax hispida* | | 20 | 20 | | .3 | .3 |
| *Vaccinium* sp. | | 10 | 10 | | .25 | .25 |

* Not distinguished as to height over or under one foot.

## b. SOILS

The soils of Ravenel's Woods are sandy loams derived from granitic parent material. In both the Rhododendron and Polycodium types, the layer of organic material not incorporated with the mineral soil is not especially thick. The undecayed litter zone is very thin and this is underlain by a zone of fermentation about one inch in thickness. A humus layer of the same thickness underlies the fermentation zone. This humus is black and more or less greasy when wet, and gradually merges into the mineral soil. The upper layer of mineral soil (to the depth of four or five inches) is very dark and contains much organic matter. Because the organic soil gradually merges with the mineral, and because of the high organic content in the mineral soil, this

3 Pteridophyte nomenclature is that of Blomquist (1934).

TABLE 2

Frequency and density of woody individuals under one inch d.b.h. in the Polycodium facies. Based on ten 2 x 2 meter plots.

| Species | Frequency over 1 ft. | Frequency under 1 ft. | Frequency all | Density over 1 ft. | Density under 1 ft. | Density all |
|---|---|---|---|---|---|---|
| Woody Reproduction | | | | | | |
| *Acer rubrum* | 10 | 60 | 60 | .1 | 2.1 | 2.2 |
| *Betula lenta* | 10 | 50 | 60 | .1 | 1.3 | 1.4 |
| *Castanea dentata* | 20 | 30 | 40 | .3 | .3 | .6 |
| *Halesia Carolina* | 10 | 20 | 20 | .1 | .4 | .5 |
| *Hamamelis virginiana* | 20 | 30 | 50 | .2 | .3 | .5 |
| *Ilex monticola* | | 10 | 10 | | .1 | .1 |
| *Magnolia Fraseri* | | 20 | 20 | | .2 | .2 |
| *Pyrularia pubera* | 10 | 10 | 10 | .1 | .4 | .5 |
| *Quercus borealis* | 10 | 30 | 30 | .1 | .3 | .4 |
| *Styrax grandifolia* | | 10 | 10 | | .1 | .1 |
| *Tsuga canadensis* | | 100 | 100 | | 2.8 | 2.8 |
| Shrubs* | | | | | | |
| *Polycodium stamineum* | | 80 | 80 | | 15.1 | 15.1 |
| *Rubus canadensis* | | 70 | 70 | | 5.5 | 5.5 |
| *Smilax hispida* | | 10 | 10 | | .4 | .4 |

* Not distinguished as to height over or under one foot.

TABLE 3

Frequency and coverage of herbaceous plants. Rhododendron type based on twenty 1 x 1 meter plots; Polycodium type based on ten 1 x 1 meter plots.

| Species | Frequency | Average percentage of cover |
|---|---|---|
| Rhododendron type | | |
| Mosses and liverworts | 70 | 7.5 |
| *Mitchella repens* | 10 | 3.25 |
| *Galax aphylla* | 20 | 1.25 |
| | Total | 12.00 |
| Polycodium type | | |
| *Arisaema triphyllum* | 20 | 0.5 |
| *Asarum virginicum* | 10 | 0.5 |
| *Boehmeria cylindrica* | 40 | 1.0 |
| *Brachyelytrum erectum* | 10 | 0.5 |
| *Dennstaedtia punctilobula* | 30 | 2.5 |
| *Dryopteris intermedia* | 50 | 6.0 |
| *Dryopteris noveboracensis* | 30 | 5.0 |
| *Galax aphylla* | 10 | 1.5 |
| *Lycopodium lucidulum* | 50 | 1.8 |
| *Lysimachia quadrifolia* | 10 | 0.1 |
| *Medeola virginiana* | 50 | 1.5 |
| *Mitchella repens* | 100 | 27.0 |
| *Oakesia sessilifolia* | 30 | 2.0 |
| *Prenanthes* sp. | 10 | 0.1 |
| *Trillium grandiflorum* | 30 | 0.5 |
| *Viola rotundifolia* | 50 | 6.5 |
| | Total | 57.00 |

surface soil can probably best be called a fine mull, following the nomenclature of Heiberg (1937). At a depth of five to six inches, the soil gradually changes to a yellowish brown sandy clay loam which probably represents the $A_2$ horizon. This horizon extends down to a depth of between ten and twelve inches where there is a gradual change to a sandy clay of the same color, the B horizon. The B horizon extends to the depth of about twenty inches where there is an abrupt change to a very sandy soil of the same color with fragments of disintegrating rock, clearly the C horizon. The whole mineral soil profile in both types is very much alike, the only difference being that, at some places in the Rhododendron type, the horizons are slightly narrower and the C horizon may be met with at a depth of only fifteen inches. The mineral soil is typified throughout by a large amount of micaceous sand. Roots are aggregated principally in the top of the profile, in the layers of high organic content.

TABLE 4

Results of the soil investigations in the form of averages.

| Collections | Organic matter % | Water holding capacity % of volume | Water holding capacity % of dry wt. | Volume weight | Air capacity % vol. | Range of pH |
|---|---|---|---|---|---|---|
| Polycodium-set 1 | 51.80 | 78.9 | 357.6 | .233 | | 3.26-3.63 |
| Polycodium-set 2 | 37.75* | 79.9* | 285.45* | .317* | | 3.37-3.57* |
| Polycodium-set 3 | 71.78 | 72.2 | 540.3 | .156 | 13.5 | 3.31-3.55 |
| Polycodium-all sets | 54.33 | 76.9 | 398.2 | .233 | 13.5 | 3.26-3.63 |
| Rhododendron-set 1 | 96.22* | 77.0 | 751.7* | .105* | 8.05 | 3.06-3.48 |
| Rhododendron-set 2 | 95.80 | 66.1 | 870.4 | .090 | 20.5 | 3.09-3.57 |
| Rhododendron-set 3 | 94.47* | 73.8 | 697.8 | .127 | 13.3 | 3.24-3.44 |
| Rhododendron-all | 95.51 | 72.3 | 776.8 | .103 | 13.3 | 3.06-3.57 |

* All primary averages based on ten samples except those so marked which are based on nine samples. All of final Polycodium averages, except air capacity, based on twenty-nine samples. Rhododendron final averages based on thirty, twenty-nine, or twenty-eight samples as indicated.

Results of the laboratory investigations on soil characteristics are presented in the form of averages in Table 4. The organic matter content in the upper layer of mineral soil is very high in both types of forest. It is, however, much higher in the Rhododendron type than it is under Polycodium. The former soil contains an average of 95.51 per cent organic matter on a dry weight basis while the latter soil averages only 54.33 per cent organic matter on the same basis. The high organic matter contents of both types are reflected in the high water-holding capacities. In the Rhododendron type, the upper mineral soil has an average water-holding capacity of 72.3 per cent of its volume, while under Polycodium, the same layer of soil holds water to the extent of 76.9 per cent of its volume. As regards this property on a volume basis, the great difference in organic matter between the soils of the two types of forest seems to have no direct effect. However, when water-holding capacity is calculated on a dry weight basis, the effect of the difference in organic content is immed-

iately shown. On this basis, the water-holding capacity of the Polycodium soil averages 398.2 per cent while that under Rhododendron, with a much higher organic content, averages 776.8 per cent, showing that, in both instances, the water-holding capacity on a dry weight basis is almost exactly proportional to the amount of organic matter present.

Another value, upon which organic matter seems to have a profound effect, is the volume-weight, or apparent specific density of the soil. The volume-weight of the Polycodium soil averages .233, a soil which is considered very light. The Rhododendron type has an even lighter soil, with an average volume-weight of only .103. As affecting volume-weight, then, the amount of organic matter in the soil is inversely proportional to the weight of the soil per unit volume. This results in a more compact soil under the Polycodium type because of the lower amount of organic matter. The air capacities of the soils on a volume basis show no apparent difference between the two types of vegetation, averaging 13.5 per cent under Polycodium and 13.9 per cent under Rhododendron. This is not entirely conclusive, however, since in measuring this particular property, only ten samples from the Polypodium type were employed, compared to thirty from the Rhododendron type.

Measurements of hydrogen-ion concentration show the soil under Rhododendron to be slightly more acid than that under Polycodium. Under the former, the range in pH is from 3.06 to 3.57, whereas under the latter, the range is from 3.26 to 3.63. This variation is insufficient as an explanation of the difference in herbaceous flora between the two types. Light must be the important factor as far as the compositions of these herbaceous synusiae are concerned.

The soil, then, under both types of vegetation is rather sandy, especially below the surface strata, and therefore has good subsoil drainage. The humus type seems to be a fine mull throughout, but containing much more organic matter under the Rhododendron than under the Polycodium. The effect of the higher organic matter content under Rhododendron is not apparent in the water-holding capacity when calculated on a volume basis, however, when this property is calculated on a weight basis, the two properties are in direct proportion to each other. Organic matter content also has a decided effect on the volume-weight of the soil, the two being inversely proportional, i.e. the higher the organic matter content, the lighter the weight of a unit volume of soil. The air capacities of the soil under both types are practically identical, while the Rhododendron soil is slightly more acid than that under Polycodium.

## Integration

The vegetation of Ravenel's Woods, as has been shown, is clearly divided into two virgin types, both under a dominant overstory of hemlock. These two types, which are separated on the basis of composition of the shrub and secondary tree synusiae, are seemingly edaphic phases or fascies of the hemlock forest community.

The hemlock forest, in the depressions and near the streams, is characterized in the secondary tree synusia by the presence of a dense tangled layer of *Rhododendron maximum* with only an occasional individual of any other species in the stratum. The shrub layer is also more or less dominated by Rhododendron canes and young plants of the same species which have developed from seeds. The Rhododendron layers cast a heavy shade which, possibly in conjunction with high soil acidity (Daubenmire, 1930), inhibits the development of a rich herbaceous flora. As a result, the herbaceous flora under the Rhododendron type consists of just two species of flowering plants, *Mitchella repens* and *Galax aphylla,* associated with a few mosses and liverworts. This sparse herbaceous synusia covers but 12 per cent of the ground surface.

Associated with the Rhododendron type of vegetation is a surface soil which is extremely high in organic matter, averaging 95.51 per cent for twenty-eight samples of the upper mineral soil from this vegetational type. The result of the high organic matter content is to give the soil a high water-holding capacity which, on a volume basis, averages 72.3 per cent. On a dry weight basis, the water-holding capacity reaches the figure of 776.8 per cent for an average of 29 samples. The high percentage of organic matter makes the soil extremely light, as is shown by an average volume-weight of only .103. This same surface soil is very acid and, for 30 samples, showed a range in pH from 3.06 to 3.57.

The Rhododendron type of forest, mainly along streams, constrasts strongly with the vegetation on the low ridges between streams. This fascies is characterized by the absence of Rhododendron in the understory and shrub layers and its replacement by *Halesia carolina* and *Hamamelis virginiana* in the secondary tree stratum and, by *Polycodium stamineum* as the characteristic shrub. The Polycodium type is further characterized by a much richer herbaceous layer covering 57 per cent of the ground and being made up of 16 species of flowering plants and ferns.

The soil under the Polycodium type is essentially the same as that under the Rhododendron except for better drainage, and a lower content of organic matter with resultant effects on other soil properties. The organic content of the mineral soil under Polycodium averages only 54.33 per cent as compared with 95.51 per cent under Rhododendron. It is difficult to ascertain whether the more open type of vegetation is responsible for the lower amount of organic matter or whether the latter factor is the cause of the open, low type of shrubby layer which is characteristic of this fascies. The true answer to this question may be that both are dependent upon another and more fundamental factor, namely topography. The tops of the low ridges, underlain with a sandy soil, provide much better drainage than obtains in the depressions where the water table is relatively nearer the surface of the soil. These differences have resulted in the development of understory and shrub synusiae on the ridges which are made up largely of relatively small, deciduous, woody species. The open nature of this lesser vegetation permits more rapid oxida-

tion of organic matter than that which takes place under the dense, evergreen Rhododendron. The resulting higher volume-weight of the mineral soil, favors maintenance of the Polycodium vegetation. The lesser amount of organic matter in the soil under Polycodium seems not to affect the water-holding capacity of a unit volume of soil when figured on a volume basis, since the value is practically the same as that for the Rhododendron type. However, the lower organic content does become apparent if water-holding capacity is computed on a dry weight basis, and it also affects the volume-weight of the soil. In the Polycodium type, the water-holding capacity on a weight basis averages 398.2 per cent contrasted to the 776.8 per cent under the Rhododendron. This difference is in direct proportion to the amount of organic matter in each soil. The volume-weight of the soil in each respective type is in inverse proportion to the amount of organic matter in the type. A unit volume of the Polycodium soil is more than twice as heavy as a corresponding volume from the Rhododendron type. The soil under Polycodium, while highly acid, is not quite so acid as that of the Rhododendron fascies, ranging from pH 3.26 to 3.63.

## Climax Relations

The ecological status of hemlock in eastern North America has been much debated. Nichols (1935), in discussing the hemlock-white pine-northern hardwood region of the Lake states and New England, considers the hemlock there to be one of several dominants in the climatic climax of the region. Concerning a virgin hemlock consociation at Hearts Content in northwestern Pennsylvania, Lutz (1930) suggests the possibility that it constitutes a physiographic climax. Morey (1936), in comparing the forest at Hearts Content with Cook Forest, another virgin forest in the same region, comes to the conclusion that the hemlock consociation is one of a group of climax communities "in the ecotone between the Lake forest and the deciduous forest formation" to the south. Associated with the hemlock community, according to Morey, are also climax communities of beech and beech-maple. These latter communities he considers as alternating with the hemlock type as the climax vegetation of the region. Hough (1936) working on the vegetation of a virgin tract on East Tionesta Creek in the same region of Pennsylvania, found the dominant vegetation to consist mainly of hemlock and beech and considers this hemlock-beech association to be the climatic climax of the area.

In the Cumberland Mountains of southeastern Kentucky, the hemlock forest which occurs in the ravines along streams, is considered by Braun (1935) as an association-segregate of the mixed mesophytic association and, therefore, as a local expression of the regional climax. Braun also suggests the possibility that these ravine communities of hemlock are of a relict nature.

Friesner and Potzger (1932, 1934), investigating isolated stands of hemlock in Indiana, outside the general range of the species, found the hemlock to be confined entirely to steep, north-facing slopes where it is frequently associated with white pine. They conclude that these hemlock outliers in

Indiana are relicts left by a former climatic climax which has been replaced by a beech-maple climax. Hemlock has thus been relegated to the status of a physiographic or edaphic climax, restricted to locations which are more or less suitable to its requirements but unsuited to beech-maple.

In Ravenel's Woods, there is abundant evidence that the hemlock vegetation is of a climax nature. In the overstory, in both the Rhododendron and the Polycodium types, hemlock makes up from fifty to seventy per cent of the dominants, having as associated species *Betula lenta, Castanea dentata, Liriodendron tulipifera, Acer rubrum, Quercus borealis* and variety *maxima*, and an occasional *Halesia carolina*. In the understory in both types of forest, several characteristic species predominate which never become a part of the dominant stratum. As a consequence, Tsuga is not quite as prominent in this synusia as it is in the overstory. However, even here, among those species which eventually become dominants, hemlock holds approximately the same position as it does in the overstory itself. The great abundance of individuals of characteristic understory species, Rhododendron in its type and *Halesia carolina* and *Hamamelis virginiana* in the Polycodium type, makes the transgressive hemlocks appear more or less scattered. However, the other potential dominants are even less apparent and there are only one or two species of such potentials present as transgressives in the understory which are not a part of the dominant stratum at the present time. The very few individuals of such species preclude the possibility of any replacement of the hemlock by them in the future unless because of cataclysmic interference. As regards the woody reproduction in both types, hemlock has a greater abundance of seedlings and small saplings than any other dominant species. All of the other dominants are also represented by seedlings which indicates that the pattern of the dominant synusia, as it now stands, in all probability, will be continued indefinitely since the relative proportion of potential dominants in all layers is approximately the same. Those tree species which are typically members of the secondary stratum under the hemlock are also reproducing in approximately the same proportions as now found in their respective types, thus indicating the equilibrium between the woody vegetation and the environment.

The possibility suggests itself that cause for the seemingly permanent nature of the characteristic patterns of species in the two types of hemlock vegetation in Ravenel's Woods and the inability of other tree species to invade may lie in the factor of soil acidity. Daubenmire (1931), working on relict hemlock communities in Indiana, comes to the conclusion that the marked acidity (pH 3.6 to 4.7) of the surface soil under hemlock, the result of hemlock growth, is probably a very important factor in excluding deciduous woody dominants and thus maintaining the hemlock relict indefinitely. The surface soil of both the Rhododendron and the Polycodium fascies of hemlock vegetation in Ravenel's Woods is extremely acid (pH 3.06 to 3.64 for 59 samples) and maintained so by the present vegetation. As long as the soil remains thus, it seems that potentially dominant deciduous species (other than those characteristically associated with virgin hemlock) may be unable to

invade the highly acid soil and thus the hemlock vegetation with its characteristic understory, shrubby, and herbaceous species, is able to continue indefinitely at Ravenel's Woods as a concrete example of a relict association segregate (Braun, 1935a) of the Tertiary mixed mesophytic climax.

## Summary and Conclusions

The hemlock forest of Ravenel's Woods is of two types based on the composition of all of the synusiae below that of the dominants. The first of these types, occurring in the depressions and along streams, is characterized by the domination of the secondary tree and the shrub synusiae by *Rhododendron maximum*, almost to the exclusion of other species. The second type, which occurs on the interstream low ridges, is typified by the absence of Rhododendron and its replacement in the secondary tree layer by several deciduous species, principally *Halesia carolina* and *Hamamelis virginiana*, and in the shrub stratum by *Polycodium stamineum*.

The stand of dominant hemlocks in the Rhododendron type is more dense than that of the Polycodium type, averaging 1.8 dominant Tsugas per 100 square meters in the former as against an average of only 0.8 for the same area in the latter type. The average basal area of the dominant hemlocks per 100 square meters is 7.835 square feet in the Rhododendron type and 4.147 square feet on the Polycodium site.

Occasional trees of other species, principally *Betula lenta* and *Castanea dentata*, share dominance with the hemlock but form only a very small part of the overstory. *Pinus strobus*, a common associate of hemlock in northern virgin hemlock forests, was not encountered in this investigation.

The reproduction of potential dominants in both types consists mainly of *Tsuga canadensis* and *Betula lenta*. The few dominants of *Castanea dentata* are, of course, doomed because of the chestnut blight and the scanty reproduction of the species is also affected, indicating its eventual disappearance from the community.

The herbaceous vegetation under Rhododendron is scanty, covering only 12 per cent of the ground and consisting of just two species of flowering plants along with mosses and liverworts. On the other hand, there is a comparatively rich herbaceous flora under Polycodium, covering 57 percent of the ground and made up of sixteen species.

The soil is mature and the humus type can probably best be called a fine mull because of the high organic matter content of the upper mineral horizon. The high content of organic matter results in a high water-holding capacity and low volume-weight. The organic matter in the upper mineral soil under Rhododendron averages 95.51 per cent on a dry weight basis, while under Polycodium, the average is only 54.33 per cent.

This difference in organic matter content between the two types results in a much lighter soil in the Rhododendron type than that under Polycodium,

the average volume-weight under the former being .103 and under the latter .233. Water-holding capacity, when calculated on a volume basis, does not seem to be affected by differences in organic matter content but, when figured on a dry weight basis, is directly proportional to the amount of organic matter in the soil.

The soils under both types of vegetation are very acid. However, that under the Rhododendron is slightly more acid, ranging from pH 3.06 to 3.57 as compared to a range of pH 3.26 to 3.63 under Polycodium.

All evidence derived from vegetation and soils indicates that the hemlock forest (both types) of Ravenel's Woods is climax. Consequently, the forest is most likely a concrete example of a relict association-segregate of the Tertiary mixed mesophytic forest. Its characteristic species-pattern has been maintained indefinitely because of its adaptation to the mountain climate and because of the inability of outside species to invade the relatively stable hemlock community. New species cannot invade or replace the characteristic relict vegetation because of their inability to meet the conditions of competition. Some of these conditions are undoubtedly edaphic handicaps associated with the effects of hemlock on soil acidity. The hemlock community, through its reactions on the environment, maintains the moist, porous, acid soil which enables its characteristic species to reproduce, thus continuing the type as a self-perpetuating relict association segregate of an ancient climatic climax.

## REFERENCES


AIKMAN, J. M. AND A. W. SMELSER. 1938—The structure and environment of forest communities in central Iowa. Ecology **19**:141-150.

BLOMQUIST, H. L. 1934—Ferns of North Carolina. Duke Univ. Press, Durham, N. C.

BRAUN, E. LUCY. 1935—The vegetation of Pine Mountain, Kentucky. Amer. Midl. Nat. **16**:517-565.

———1935a—The undifferentiated deciduous forest climax and the association-segregate. Ecology **16**:514-519.

CAIN, STANLEY A. 1931—Studies on virgin hardwood forest: I—Density and frequency of the woody plants of Donaldson's Woods, Lawrence County, Indiana. Proc. Indiana Acad. Sci. **41**:105-122.

———1934—Studies on virgin hardwood forest: II—A comparison of quadrat sizes in a quantitative phytosociological study of Nash's Woods, Posey County, Indiana. Amer. Midl. Nat. **15**:529-566.

———1935—Studies on virgin hardwood forest: III—Warren's Woods, a beech-maple climax forest in Berrien County, Michigan. Ecology **16**:500-513.

———1938—The species-area curve. Amer. Midl. Nat. **19**:573-581.



DUKE UNIVERSITY
AND
UNIVERSITY OF NEVADA.

DAUBENMIRE, REXFORD F. 1930—The relation of certain ecological factors to inhibition of forest floor herbs under hemlock. Butler Univ. Bot. Studies **1**:61-76.

———1931—Factors favoring the persistence of a relic association of eastern hemlock in Indiana. Butler Univ. Bot. Studies **2**:29-32.

———1936—The "Big Woods" of Minnesota: its structure and relation to climate, fire, and soils. Ecol. Monogr. **6**:235-268.

EGGLER, W. A. 1938—The maple-basswood forest type in Washburn County, Wisconsin. Ecology **19**:243-263.

FRIESNER, RAY C. AND J. E. POTZGER. 1932—Studies in forest ecology. II. The ecological significance of *Tsuga canadensis* in Indiana. Butler Univ. Bot. Studies **2**:145-149.

———1934—Climax conditions and the ecological status of *Pinus strobus*, *Taxus canadensis* and *Tsuga canadensis* in the Pine Hills region of Indiana. Butler Univ. Bot. Studies **3**:65-83.

HEIBERG, S. O. 1937—Nomenclature of forest humus layers. Journ. Forestry **35**:36-39.

HOUGH, A. F. 1936—A climax forest community on East Tionesta Creek in northwestern Pennsylvania. Ecology **17**:9-28.

LUTZ, H. J. 1930—The vegetation of Hearts Content, a virgin forest in northwestern Pennsylvania. Ecology **11**:1-29.

———1930a—Effect of cattle grazing on the vegetation of a virgin forest in northwestern Pennsylvania. Journ. Agri. Res. **41**:561-570.

———1934—Additions to the flora of Hearts Content, a virgin forest of northwestern Pennsylvania. Ecology **15**:295-297.

MOREY, H. F. 1936—A comparison of two virgin forests in northwestern Pennsylvania. Ecology **17**:43-55.

———1936a—Age-size relationships of Hearts Content, a virgin forest in northwestern Pennsylvania. Ecology **17**:251-257.

NICHOLS, G. E. 1913—The vegetation of Connecticut: II. Virgin forests. Torreya **13**:199-215.

———1935—The hemlock-white pine-northern hardwood region of eastern North America. Ecology **16**:403-422.

POTZGER, J. E. AND RAY C. FRIESNER. 1934—Some comparisons between virgin forest and adjacent areas of secondary succession. Butler Univ. Bot. Studies **3**:85-98.

# Plant Migration in the Southern Limits of Wisconsin Glaciation in Indiana[1]

J. E. Potzger and Ray C. Friesner

Vegetation is always an expression of the climate and as climate changed great masses of vegetation developed, advanced, retreated or in many instances perished leaving only the carbonized remains deep in the strata in parts of the globe where today cheerless winds blow monotonously over bleak ice and snow-fields thousands of feet in depth. By these fragments of former vegetation we today piece together not only part of the story of the advance, conquest and fall of mighty vegetations, but also the story of the climate which made that plant life possible. The uniformity of the pre-Pleistocene vegetation from pole to pole (Huntington and Visher, 1922) speaks of a monotonously uniform climate all over the world. In the more recent Pleistocene vegetation the conquest was between species which still today are in battle array, advancing and retreating with climatic fluctuations. While pre-Pleistocene time is marked by uniformity, post-Pleistocene climate is outstanding by its diversity and complexity.

We are in the present study concerned with a story of vegetation whose echo is still heard about our polar regions, records of whose forests are still neatly packed in the archives of our bogs, and whose straggling rear guards in areas of more moderated climate are making a last stand in small isolated relic colonies to fight a losing battle against the advancing climatically favored masses of more southern broad-leaved species, but whose main body constitutes poleward a vast belt of unbroken boreal forest. Piecing together the story of these retreating forest boundaries throws light on climatic and geological changes as well as on phytosociological laws and the competition between the two most extensive forest formations in North America.

As we view the present status of the battle, we ask, "How far had deciduous species been forced equatorward?" In Europe the path for the retreat was limited by the Mediterranean Sea and east-west mountain ranges, and here Carya, Sassafras, Liquidambar, Benzoin, Hamamelis and others made their last stand and perished. North America offered a wider sweep, for unbroken landmasses without east-west mountain barriers permitted free movement from the north to semi-tropical latitudes. While Indiana is without doubt one of the most important southernmost outposts of very obvious glacial influence, depressions of northern life as far south as the borders of Florida are claimed by Hanna (1933) who says, "We are not justified in assuming that even during the maximum extension of the ice sheet conditions were as favorable for the accumulation of peat in Florida as they are in the Great

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1 A paper read before the Systematic Section of the Botanical Society of America in the Symposium: The Origin and Distribution of the Flora of the Middle West.

Lakes region today. Nevertheless, it does seem safe to conclude that during a period of 30,000 years or more, a period probably coincident with one of the ice sheets, the climate of Florida did not differ greatly from that of the northern part of the United States at present." Recently very concrete evidence was produced by Brown, Steere and others (1938) that boreal species extended their range to the region about Baton Rouge, Louisiana. These workers found remains of such boreal tree species as *Picea canadensis, Thuja occidentalis, Larix laricina,* besides herbaceous species, several mosses, and mollusks. If climatic control of these species during Pleistocene time was the same as that apparent today, and there appears no reason for thinking otherwise, we must assume that climate comparable to that of Michigan between Grand Rapids and Saginaw and northward existed to within a short distance of the Gulf of Mexico. From the records found in the Louisiana deposits Brown (1938) concludes that the boreal species did not displace the southern broad-leaved species entirely but only those which had a narrow range of adaptability to temperature changes, and the boreal species occupied the microclimatically controlled less favorable areas within the more southern type of vegetation. These in all probability were mostly wet lowlands which were evidently cooled considerably by the immense volumes of icy waters which poured down the Mississippi River. Of course, isolated fossil evidence cannot well give so complete a picture as a pollen spectrum, but there is no reason at all why the boreal forest did not bear at its southern periphery during Pleistocene times the same "patchy" distribution as one finds in its southern periphery of today, i.e. from Ohio and Indiana northward to the Canadian border.

A number of papers on fossil pollen from peat bogs in the more southern limits of the Illinoian and Wisconsin glaciation have appeared during the last few years and deductions are made as to climatic conditions in these southern limits during any particular cycle of years as reflected by the pollen spectrum. Usually the great boreal belt is reflected as a static stabilized entity, marking time within its present boundaries. But a new angle to the question was presented in the papers by Cooper (1931) and Griggs (1934) on the limits of the boreal forest in Alaska. Cooper (1931) reports retreat of glaciers at Glacier Bay with accompanying advance of vegetation. Griggs (1914) says the following about the Kodiak region in southeastern Alaska, "The advance is so rapid that it is evident to persons who have lived in Kodiak only a few years." This was in 1914. Twenty years later he repeats the same statement, only now it is even more significant because it involves measurable and observable advance. He says, (1934) "In the light of practically unanimous opinion of observers on the ground it seems justifiable to generalize and to conclude that in many places in Alaska the forest boundaries are mobile migration fronts rather than static climatic boundaries." In this same paper he asks the following question, "Have the scores of boreal species which stretch far south along the eastern mountains been holding their own or are they slowly receding? The marginal individuals in all such cases would give decisive testimony, for by studying these individuals which are in direct competition with plants of other formations it can be seen whether they are gaining or losing in the struggle."

That is a very important and interesting question. However, it appears to the writers that the best place for such a study would be a border area where topography would be more or less uniform in elevation and where pollen records of early vegetational history could augment the story of the vegetation of today. Indiana is ideally located for such a study, it is a keystone area in the great lane of migration of boreal and broad-leaved forests and for that reason we will in the present paper attempt to answer, at least partially, the question asked by Dr. Griggs with facts gleaned from data of pollen studies and from static relic colonies of boreal species in Indiana, and try to show relationships between the two borders of the vast boreal forest in North America.

**Vegetation and Climate**

In an investigation of this nature one will be confronted with the problem of comparing climates and forest fronts in the Arctic of today as a line moved to a higher latitude from a once lower latitude. Certain features are comparable while others of necessity are, because of latitudinal differences, not comparable. Just how great must the difference be in climatic depression to displace the broad-leaved forest and initiate the advent of a boreal forest? Was the boreal forest in post-Pleistocene times approximately the same width as today and has it been displaced only in latitude? Can we compare the outpost of the northern timber-line of today with the post-Pleistocene line in Indiana? These and many other questions enter into such a problem. While we will probably not be able to answer these questions definitely, we must at least attempt to project such facts into a paleobotanical problem if we hope to analyze the data shown in pollen spectra with any degree of correctness.

Another factor which must be considered is whether or not environmental control at the northern limit, i.e. the advance-margin, is simpler or more complex than the one in the southern tension zone, i.e. on the retreating margin. Comparing the two tension lines we must admit that the latitudes in the two cases most certainly make a big difference. Indiana was probably the scene of the retreating fringe of the boreal forest for a longer period of time than the forest front in the north is of the advance margin today. One might expect a more rapid retreat of glaciers when the primary cause of glaciation was removed or modified, and a more rapid advance of vegetation, provided the moisture conditions were satisfactory.

Hanna (1933) concludes after a study of the micro-flora in peat deposits of Florida that the climate of Florida "did not differ greatly from that of the northern part of the United States at present." He found the diatom flora "essentially a northern one, subarctic at the present time," and concludes, "It is probable that the diatom-bearing peat of Florida accumulated at the time of the maximum southerly expansion of the ice sheet." What do climatologists and students of glaciation say? Huntington and Visher (1922) say, "A change of even 2° C above or below the present level of the earth's mean temperature would be of very appreciable climatic significance, for it is commonly believed that during the height of the glacial period the mean temperature was only 5 to 8° C lower than now" (pp. 39-40). These

authors champion the solar cyclonic hypothesis theory. They feel that variations in precipitation have had much more to do with glaciation than have variations in extreme temperature. They say, "In the arctic lowlands on the leeward side of mountains the slight development of glaciation appears to have been due to scarcity of precipitation." Thwaites (1937) feels that in spite of the fact that cold winds must periodically have descended from the ice caps, life conditions not far from the ice front in southern latitudes may have been little worse than in the south of today when a "norther" blows. He also feels that the edges of the ice were thrust far down into the zone of wastage.

Summing up these opinions we may assume that glaciation in its southern extension was not necessarily associated with extremely low temperatures, in fact, a moderate temperature is more likely than an extremely low one, and no doubt there was a shorter period of lowered winter temperature than we have near the Arctic Circle today, because of greater and more extensive solar heat influence. We are at times inclined to assume great differences in environmental factors between two strikingly different vegetation types, while in reality the initial deviation might be very slight. Huntington and Visher (1922) point this out when they say, "We have seen how delicate is the balance among the forces of Nature even though they be of the most stupendous magnitude" (p. 135). So even today sharp zonations in vegetation types are induced by differences in environmental factors due to differences in slope of hills (Potzger, 1939).

If it was not extremely low temperature of the air which checked the post-glacial advance of the broad-leaved species, what was the control? No doubt the wind blowing from the ice fields and its desiccating influence affected both transpiration and evaporation from the soil. Much of the soil water was cooled by the cold ice water from melting glaciers. Such a sensitive control of spruce and fir in competition with broad-leaved species has been observed on Mackinac Island, Michigan (Potzger, Ms.). Here the broad-leaved species are limited to the central portion of the island. No doubt the lower soil temperature, especially in winter, along the high slopes of the outer rim of the island selects the more xerophytic conifers for the outer belt. On Mount Stratton in Vermont balsam fir is limited almost to the top-most five hundred feet and there forms an almost pure fir forest, while the foot of the mountain supports mainly broad-leaved species.

Comparing the two peripheral zones of the boreal forest, i.e. the advancing zone of the north and the retreating zone of the south, we believe that advance on the northern outpost is faster and more readily noticeable because the problem there is one chiefly of selection of suitable habitat, while in the southern limit tension zone the factors are complicated by both microclimate and competition of species, which will retard advance and make a quantitative observation more difficult. We would conclude, therefore, that advance on the north limits was more rapid than retreat on the south limits.

Friesner (1937) has shown that Indiana is a critical botanical area, for across its surface moved vast vegetations from strikingly different climatic

belts and left in its present vegetation tell-tale relic colonies. These relic colonies are for the most part of two types, viz. boreal relics and prairie relics. The boreal relics are remnants of boreal vegetation once widespread over the state but now reduced to mere vegetational islands in a mass of more temperate flora. Relic colonies are always limited to the rear fringes of a retreating vegetation.

Bacon's Swamp in Indianapolis is no doubt one of the southernmost bogs associated with Wisconsin glaciation. Here in Indiana, then, was once the vanguard of the boreal forest which today has marched 1500 miles to the north. The state is a comparatively flat plain where altitudinal control of vegetation does not obscure the migration story. So we believe that here in Indiana rather than in the eastern mountains, as suggested by Griggs (1934), should a comparative study of migrating forests be made.

## Evidences of Migrating Forests

### Northern or Advancing Border

According to reports from all investigators along the timber line of the north, glaciers are retreating and forests are advancing. How long this condition may continue time only will tell. According to Huntington and Visher (1922) "marked changes in climate are initiated more rapidly than they disappear" and man is ever impatient to try to force results into the straight jacket of the years of a life time. In the north advances are sufficiently rapid to make observation of progress noticeable. Griggs (1934) says that the trees at the edge of the forest are all young, none over one hundred years of age. Trees 319 years of age are now about three miles to the rear of the advancing front. He says further, "In 1867 Long Island was called Bare Island because it had but a few scattered patches of trees." In less than seventy years the island has received a heavy stand of timber. One hundred forty years ago the dwellers of Kodiak had to get their wood from Cape Chinick, 20 miles away; today the forest has advanced to within easy reach of the village. From another section of Alaska, Glacier Bay, Cooper (1931) reports similar advances of vegetation, which also is easily seen from the pictures of some of his permanent quadrats. He says, "Thirteen years later there was evident a very decided greening of the lower slope in many places." According to current newspaper accounts, the Russian workers found the forest advancing northward in Europe. According to Griggs (1934) the forest advanced an average of one mile in seven years. Cooper (1931) found a similar rate of advance on Russell Island and at another place nine miles in fourteen years, while at Muir Inlet outliers of vegetation had advanced seven miles in four years. These are easily observable and measurable quantities.

### Southern or Retreating Border

Two lines of approach are available for study of the behavior of forest migration on its retreating border, viz. relic colonies and fossil records. Spruce and fir had already vanished from Indiana when civilized man moved in, but the more semi-boreal species, Thuja, Larix, *Pinus strobus,* as well as species

from the shrub and herbaceous layers, still persisted as isolated relic colonies in circumscribed areas where microclimatic conditions in bogs and on cliffs favored them because of their greater potentiality to meet more rigorous edaphic conditions and problems. Vast deposits of Larix and Thuja logs (Potzger, 1936) in peat, pollen of pine and Larix up to the one-foot level of peat and absence of these genera in the vegetation complex when civilized man appeared tell a graphic story of retreating forests.

The southernmost bogs in Indiana all speak of old age, their chapter is closed; most of them had even passed the sedge-meadow stage. Most of them have been very deep lakes and all so far studied have 1 to 14 feet of marl deposit (Potzger, 1938). All of them are within the borders of the Early and Late Wisconsin glaciation. The bogs of the more northern tiers of counties had not all been conquered by the broad-leaved forest when the state became settled. Merrillville Bog of Lake County was and still is controlled by *Pinus strobus*. It is one of the few stations where this species still holds itself in Indiana, but according to Lindsey (1932) it is now gradually being displaced by Quercus.

While the semi-boreal species Larix and Thuja were found in a number of bogs even as far south as Richmond, Indiana (Markle, 1915) they have passed with the modifying influence of civilized man. Tamarack swamps persisted at Delong and near Monterey in Cass County until recent times but the bog at Lake Cicott, 35 miles to the south, had already been conquered by deciduous species when settlers moved in a hundred years ago.

In Cranberry Pond of Madison County cranberries persisted up to fifteen years ago but they have disappeared since that time. *Betula pumila* on its retreating margin is reduced to a few straggling stems in the Kokomo bog (Howell, 1938), its southernmost outpost of today.

All of these records point to a retreating northern vegetation, the semi boreal element repeating the retreat of the boreal species.

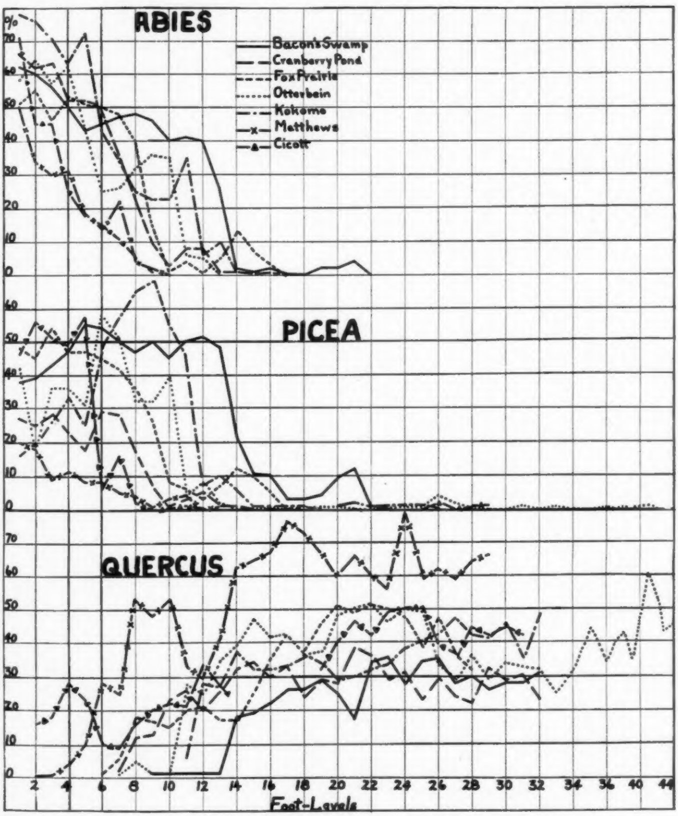
## Pollen Records

The original data upon which the conclusions regarding forest migrations in this paper are based were taken from seven bogs all of which occur within the borders of Early and Late Wisconsin glaciation in Indiana. These bogs with their locations and workers who obtained the original data are as follows:

| | | | |
|---|---|---|---|
| Bacon's Swamp | Indianapolis, Marion County | Otto | (1938) |
| Cranberry Pond | Emporia, Madison County | Barnett | (1937) |
| Fox Prairie | Noblesville, Hamilton County | Prettyman | (1937) |
| Otterbein | Otterbein, Warren County | Richards | (1938) |
| Kokomo | Kokomo, Howard County | Howell | (1938) |
| Matthews | Matthews, Grant County | Potzger | |
| Lake Cicott | Lake Cicott, Cass County | Smith | (1937) |

All seven bogs have as a whole the same message, and the uniform sequence of forest dominants, Abies to Picea to Quercus or Quercus-Carya, (Tables 1 and 2), is quite striking. While general sequence of forest succession is the same in principle for all bogs the details vary with each area. At

Bacon's Swamp, the area farthest south (at Indianapolis), the sequence of dominants has been: Abies to Picea to Quercus to Quercus-Carya to Quercus to Quercus-Acer. This is the only area under present study showing a definite Quercus-Acer dominance. At Cranberry Pond, 30 miles farther northeast, the sequence of dominants was Abies to Abies-Picea to Larix-Quercus to Pinus Quercus to Quercus to Quercus-Carya. At Kokomo, 50 miles north of Bacon's, the sequence of dominants was Abies to Picea to Quercus, while at Otterbein, 45 miles west of Kokomo on the same latitude, the sequence was exactly the same except for a brief recovery of Abies during Picea dominance. At Lake Cicott, 20 miles farther north than the last two areas and on a longitude about equidistant between them, the sequence showed a Pinus dominance replacing Picea, otherwise the same.



In all of the above sequences other species were present, but in no case were the other species sufficiently abundant to yield evidence of the return of the undifferentiated deciduous forest climax shown by Miss Braun (1935) to have been present in pre-glacial times. The complete sequences of all genera are given in Table 2 where every change in forest content is noted together with the bog-levels at which the changes occurred.

The outstanding features of post-glacial forest migration are the earliest dominance of Abies, a later dominance of Picea (except that at Lake Cicott Abies is followed by a period of dominance by Pinus instead of Picea), and a final dominance of Quercus with or without codominants of Carya or Acer. These features are graphically shown in the curves of Figs. 1-3. A study of these curves shows that Abies and Picea have very similar behavior except that the high points of Abies' abundance come earlier than those for Picea; that while these two genera are high in abundance Quercus is low, and that as the curves for Abies and Picea fall that for Quercus rises.

In formulating a conception of forest migration it is often difficult to

TABLE 1. Pollen abundance from seven bogs: B—Bacon's Swamp, Marion county; C—Cranberry Pond, Madison county; F—Fox Prairie, Hamilton county; O—Otterbein, Warren county; K—Kokomo, Howard county; M—Matthews, Grant county; L—Lake Cicott, Cass county. Foot-levels are numbered from the bottom upward. Figures are percentages of 200 pollen counts. Depth of bog in each case is indicated by a horizontal line.

**Abies**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | | | | |
| 43 | | | | | | | |
| 42 | | | | | | | |
| 41 | | | | | | | |
| 40 | | | | | | | |
| 39 | | | | | | | |
| 38 | | | | | | | |
| 37 | | | | | | | |
| 36 | | | | | | | |
| 35 | | | | | | | |
| 34 | | | | | | | |
| 33 | | | | | | | |
| 32 | — | — | | | — | | |
| 31 | | | | | | | — |
| 30 | | | | | | | |
| 29 | | | | | | — | |
| 28 | | | — | | | | |
| 27 | | | | | | | |
| 26 | | | | | | | |
| 25 | | | | | | | |
| 24 | | | | | | | |
| 23 | | | | | | | |
| 22 | | | | | | | |
| 21 | 4 | | | | | | |
| 20 | 2 | | | | | | |
| 19 | 2 | | | | | | |
| 18 | | | | | | | |
| 17 | ½ | | ½ | | | | |
| 16 | 2 | ½ | 3 | ½ | | | |
| 15 | 1 | ½ | 7 | | | | |
| 14 | 2 | 1 | 13 | | 1 | | |
| 13 | 26 | 1 | 5 | ½ | 10 | | |
| 12 | 40 | 8 | ½ | 5 | 6 | | |
| 11 | 41 | 8 | 4 | 6 | 35 | | 2 |
| 10 | 40 | 3 | 1 | 35 | 23 | | 2 |
| 9 | 46 | 10 | 16 | 36 | 23 | | 1 |
| 8 | 48 | 23 | 40 | 32 | 25 | 4 | 5 |
| 7 | 47 | 36 | 48 | 26 | 35 | 22 | 11 |
| 6 | 45 | 51 | 50 | 25 | 43 | 4 | 15 |
| 5 | 43 | 52 | 51 | 43 | 72 | 19 | 18 |
| 4 | 50 | 52 | 53 | 62 | 63 | 31 | 26 |
| 3 | 56 | 63 | 46 | 57 | 71 | 30 | 35 |
| 2 | 60 | 62 | 55 | 64 | 76 | 34 | 35 |
| 1 | 62 | 66 | 51 | 58 | 78 | 50 | 71 |

**Picea**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | | | | |
| 43 | | | | | | | |
| 42 | | | | | | | |
| 41 | | | | 1 | | | |
| 40 | | | | ½ | | | |
| 39 | | | | | | | |
| 38 | | | | ½ | | | |
| 37 | | | | | | | |
| 36 | | | | ½ | | | |
| 35 | | | | | | | |
| 34 | | | | | | | |
| 33 | | | | ½ | | | |
| 32 | — | — | | | — | | |
| 31 | | | | 1 | | | — |
| 30 | | | | | | | |
| 29 | | | | | | $\overline{1}$ | |
| 28 | | | — | ½ | | 1 | |
| 27 | | | | 2 | | | |
| 26 | | | | 4 | ½ | 2 | |
| 25 | | | | ½ | 1 | | |
| 24 | | | | ½ | 1 | | |
| 23 | | | | | 1 | 1 | |
| 22 | 1 | | | | ½ | 2 | |
| 21 | 12 | | | | 2 | 2 | |
| 20 | 9 | | | ½ | 1 | | |
| 19 | 4 | | | ½ | 1 | | 1 |
| 18 | 3 | | ½ | ½ | 1 | | |
| 17 | 3 | | | | 1 | | |
| 16 | 10 | | 5 | ½ | ½ | | |
| 15 | 11 | | 10 | | 1 | | |
| 14 | 22 | 1 | 12 | | 6 | | |
| 13 | 48 | 1 | 7 | 2 | 10 | | 1 |
| 12 | 51 | 5 | 3 | 8 | 7 | ½ | |
| 11 | 50 | 3 | 6 | 4 | 46 | ½ | 4 |
| 10 | 45 | 1 | 8 | 40 | 55 | ½ | 3 |
| 9 | 50 | 7 | 26 | 32 | 68 | | 1 |
| 8 | 47 | 17 | 36 | 32 | 65 | 2 | 4 |
| 7 | 50 | 28 | 42 | 51 | 57 | 16 | 5 |
| 6 | 54 | 29 | 45 | 58 | 49 | 6 | 8 |
| 5 | 55 | 18 | 47 | 31 | 25 | 57 | 8 |
| 4 | 47 | 23 | 47 | 36 | 33 | 49 | 11 |
| 3 | 43 | 28 | 54 | 36 | 26 | 51 | 9 |
| 2 | 39 | 25 | 45 | 18 | 20 | 56 | 18 |
| 1 | 38 | 27 | 48 | 42 | 16 | 46 | 20 |

**Pinus**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | $\overline{5}$ | | | |
| 43 | | | | 4 | | | |
| 42 | | | | 2 | | | |
| 41 | | | | 1 | | | |
| 40 | | | | 2 | | | |
| 39 | | | | 1 | | | |
| 38 | | | | 2 | | | |
| 37 | | | | 7 | | | |
| 36 | | | | 5 | | | |
| 35 | | | | 5 | | | |
| 34 | | | | 11 | | | |
| 33 | | | | 3 | | | |
| 32 | $\overline{6}$ | $\overline{5}$ | | 3 | $\overline{3}$ | | |
| 31 | 6 | 12 | | 4 | 7 | | $\overline{1}$ |
| 30 | 10 | 8 | | 2 | 4 | | 2 |
| 29 | 8 | 9 | | 2 | 3 | $\overline{4}$ | 8 |
| 28 | 6 | 11 | $\overline{2}$ | 3 | 2 | | 2 |
| 27 | 4 | 8 | 3 | 2 | 2 | 7 | 3 |
| 26 | 4 | 4 | 2 | 8 | 2 | 10 | 6 |
| 25 | 6 | 4 | | 7 | 1 | | 1 |
| 24 | 4 | 1 | 1 | 5 | 1 | 5 | 4 |
| 23 | 3 | 1 | 2 | 6 | 2 | 2 | 3 |
| 22 | 4 | 1 | 2 | 3 | 1 | 12 | 3 |
| 21 | 23 | 2 | 1 | 5 | ½ | 4 | 3 |
| 20 | 8 | ½ | 2 | 3 | ½ | 3 | 4 |
| 19 | ½ | ½ | 1 | 4 | 1 | 4 | 3 |
| 18 | ½ | 1 | 4 | 3 | 1 | 3 | |
| 17 | 1 | 5 | 5 | ½ | 2 | | |
| 16 | 2 | 2 | 19 | ½ | 2 | | |
| 15 | ½ | 6 | 9 | 1 | 1 | 2 | |
| 14 | 5 | 14 | 6 | 2 | 8 | 1½ | |
| 13 | 3 | 22 | 3 | 5 | 17 | ½ | 3 |
| 12 | ½ | 16 | 2 | 9 | 10 | ½ | 8 |
| 11 | 1 | 10 | ½ | 3 | 3 | ½ | 28 |
| 10 | 3 | 3 | ½ | 17 | 6 | | 41 |
| 9 | 2 | 8 | | 17 | 5 | ½ | 54 |
| 8 | 1 | 12 | | 2 | 6 | 9 | 51 |
| 7 | 1 | 18 | | 13 | 7 | 6 | 55 |
| 6 | 1 | 15 | | 5 | 8 | ½ | 48 |
| 5 | 1 | 17 | | 19 | 3 | | 16 |
| 4 | 1 | 18 | | 2 | 4 | 1 | 3 |
| 3 | | 8 | | 6 | 3 | 1 | 4 |
| 2 | | 13 | | 16 | 4 | ½ | 10 |
| 1 | | 7 | | | 6 | ½ | 8 |

**Quercus**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | $\overline{45}$ | | | |
| 43 | | | | 43 | | | |
| 42 | | | | 52 | | | |
| 41 | | | | 60 | | | |
| 40 | | | | 47 | | | |
| 39 | | | | 35 | | | |
| 38 | | | | 42 | | | |
| 37 | | | | 40 | | | |
| 36 | | | | 34 | | | |
| 35 | | | | 44 | | | |
| 34 | | | | 32 | | | |
| 33 | | | | 25 | | | |
| 32 | $\overline{31}$ | $\overline{23}$ | | 32 | $\overline{48}$ | | |
| 31 | 28 | 30 | | 33 | 36 | | $\overline{42}$ |
| 30 | 28 | 29 | | 34 | 45 | | 44 |
| 29 | 26 | 32 | | 29 | 41 | $\overline{66}$ | 42 |
| 28 | 30 | 22 | $\overline{32}$ | 36 | 42 | 64 | 44 |
| 27 | 28 | 24 | 36 | 29 | 47 | 59 | 36 |
| 26 | 35 | 29 | 47 | 34 | 42 | 62 | 39 |
| 25 | 34 | 23 | 38 | 49 | 40 | 59 | 50 |
| 24 | 28 | 31 | 47 | 50 | 38 | 79 | 50 |
| 23 | 35 | 29 | 50 | 46 | 33 | 56 | 49 |
| 22 | 34 | 36 | 51 | 51 | 32 | 60 | 42 |
| 21 | 17 | 38 | 49 | 50 | 30 | 66 | 46 |
| 20 | 25 | 28 | 51 | 48 | 29 | 60 | 40 |
| 19 | 29 | 29 | 45 | 37 | 34 | 67 | 32 |
| 18 | 26 | 24 | 37 | 36 | 36 | 73 | |
| 17 | 26 | 33 | 42 | 42 | 33 | 76 | |
| 16 | 22 | 30 | 35 | 41 | 32 | 67 | |
| 15 | 19 | 34 | 25 | 47 | 32 | 42 | |
| 14 | 18 | 32 | 17 | 39 | 37 | 62 | |
| 13 | 1 | 26 | 17 | 35 | 27 | 41 | 28 |
| 12 | 1 | 20 | 21 | 25 | 28 | 30 | 33 |
| 11 | 1 | 26 | 20 | 28 | 6 | 33 | 21 |
| 10 | 1 | 23 | 15 | 1 | | 53 | 22 |
| 9 | 1 | 13 | 17 | 1 | | 48 | 20 |
| 8 | | 12 | 18 | 5 | | 53 | 16 |
| 7 | | 2 | 6 | 1 | | 25 | 9 |
| 6 | | | 1 | | | 28 | 10 |
| 5 | | | | | | 10 | 23 |
| 4 | | | | | | 4 | 28 |
| 3 | | | | | | 1 | 18 |
| 2 | | | | | | ½ | 16 |
| 1 | | | | | | | |

| Foot Level | Carya | | | | | | | Acer | | | | | | | Fagus | | | | | | | Betula | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | C | F | O | K | M | L | B | C | F | O | K | M | L | B | C | F | O | K | M | L | B | C | F | O | K | M | L |
| 44 | | | | 17 | | | | | | | 6 | | | | | | | | | | | | | | 2 | | | |
| 43 | | | | 22 | | | | | | | | | | | | | | | | | | | | | 2 | | | |
| 42 | | | | 11 | | | | | | | 1 | | | | | | | | | | | | | | 4 | | | |
| 41 | | | | 10 | | | | | | | 2 | | | | | | | | | | | | | | 1 | | | |
| 40 | | | | 18 | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | |
| 39 | | | | 16 | | | | | | | 3 | | | | | | | | | | | | | | 1 | | | |
| 38 | | | | 22 | | | | | | | 2 | | | | | | | | | | | | | | 4 | | | |
| 37 | | | | 14 | | | | | | | 5 | | | | | | | | | | | | | | 2 | | | |
| 36 | | | | 16 | | | | | | | 4 | | | | | | | | | | | | | | 2 | | | |
| 35 | | | | 10 | | | | | | | 4 | | | | | | | | | | | | | | 4 | | | |
| 34 | | | | 12 | | | | | | | 10 | | | | | | | | | | | | | | 2 | | | |
| 33 | | | | 16 | | | | | | | 11 | | | | | | | | | | | | | | 2 | | | |
| 32 | 8 | 11 | | 10 | 11 | | | 22 | | | 20 | 2 | | | 12 | 5 | | | 1 | | | | 1 | | 6 | 6 | | |
| 31 | 17 | 12 | | 8 | 10 | | 25 | 23 | | | 18 | 2 | | 1 | 13 | 3 | | | 3 | | | | 1 | | 2 | 13 | | |
| 30 | 10 | 16 | | 13 | 12 | | 21 | 23 | | | 16 | 2 | | 2 | 13 | 4 | | | 2 | | | | 1 | | 4 | 16 | | |
| 29 | 17 | 19 | | 22 | 12 | | 23 | 20 | | | 9 | 3 | 4 | 1 | 7 | 4 | | | 5 | | | | ½ | | 2 | 17 | | ½ |
| 28 | 16 | 17 | | 16 | 19 | 2 | 19 | 17 | | | 12 | 3 | 10 | 1 | 12 | 7 | | | 1 | | | | ½ | | 2 | 17 | | 1 |
| 27 | 17 | 19 | 16 | 11 | 18 | 4 | 17 | 16 | 3 | 3 | 20 | 2 | 4 | 1 | 4 | 2 | | | 1 | | ½ | | 2 | 2 | 1 | 9 | 1 | |
| 26 | 17 | 28 | 18 | 6 | 23 | 4 | 17 | 15 | 6 | 6 | 18 | 3 | | 1 | 2 | 2 | | | 2 | | ½ | | ½ | 3 | 2 | 4 | | ½ |
| 25 | 20 | 25 | 7 | 10 | 24 | 6 | 17 | 12 | 6 | 6 | 8 | 5 | 7 | 1 | 1 | 4 | | | 3 | | ½ | | | 2 | 1 | 2 | | ½ |
| 24 | 27 | 28 | 11 | 12 | 20 | 7 | 16 | 13 | 3 | | 3 | 8 | 1 | 3 | | 1 | | | 3 | | | ½ | 1 | 3 | 1 | 2 | | |
| 23 | 25 | 22 | 11 | 7 | 18 | 13 | 21 | 10 | 2 | 3 | 1 | 6 | 2 | 1 | | 1 | | | 2 | | | | 3 | | 1 | 2 | 2 | |
| 22 | 27 | 30 | 12 | 7 | 22 | 2 | 18 | 7 | 1 | 6 | 3 | 7 | | 1 | | 2 | | | 4 | | | | 3 | 2 | 1 | 3 | | ½ |
| 21 | 6 | 25 | 8 | 7 | 17 | 4 | 15 | 3 | | 6 | 1 | 7 | 2 | 2 | | 2 | | | 4 | | | 2 | 1 | ½ | 1 | 3 | 2 | ½ |
| 20 | 8 | 25 | 11 | 8 | 17 | 3 | 22 | 1 | ½ | 3 | 2 | 10 | 3 | 1 | | ½ | | | 2 | | | 2 | 1 | 1 | 1 | 5 | | 2 |
| 19 | 6 | 19 | 11 | 10 | 18 | 4 | 19 | 2 | | 2 | 4 | 8 | 7 | ½ | | 2 | | | | | | 4 | 3 | 5 | 1 | 5 | | 8 |
| 18 | 4 | 21 | 10 | 4 | 16 | 5 | | | | 1 | 12 | 5 | 7 | | | | | | | | | 5 | 7 | 2 | 2 | 7 | | |
| 17 | 5 | 11 | 8 | 9 | 11 | 4 | | | | | 4 | 9 | 6 | | | 1 | | | | | | 7 | 5 | 6 | 3 | 9 | 1 | |
| 16 | 4 | 11 | 6 | 5 | 11 | 8 | | | | ½ | 3 | 2 | 3 | | | | | | | | | 3 | 11 | 3 | 2 | 13 | 4 | |
| 15 | 2 | 10 | 2 | 5 | 11 | 6 | | | | | | 5 | | | | | | | | | | 10 | 8 | 2 | 3 | 16 | 3 | |
| 14 | 2 | | 2 | 10 | | 27 | | | | | | 1 | 6 | | | | | | | | | 12 | 6 | 3 | 4 | 10 | ½ | |
| 13 | ½ | | | 5 | | 10 | 12 | | | | | | | | | | | | | | | 3 | 5 | 5 | 4 | 11 | 1 | 8 |
| 12 | 2 | ½ | 1 | | | 8 | 9 | | | | | | 5 | | | ½ | | | | | | ½ | 7 | 11 | 6 | 10 | 2 | 20 |
| 11 | ½ | | 4 | | | 10 | 4 | | | | | | | | | | | | | | | ½ | 9 | 7 | 2 | 3 | ½ | 16 |
| 10 | 1 | | 2 | | | ½ | | | | | | | | | | 1 | | | | | | 1 | 16 | 6 | | | 3 | 14 |
| 9 | | | 1 | | | | | | | | | | | | | | | | | | | | 9 | 3 | 1 | | 7 | 13 |
| 8 | | | 5 | | | | | | | | | | | | | | | | | | | | 7 | 1 | 2 | | ½ | 12 |
| 7 | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | ½ | 10 |
| 6 | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | ½ | 11 |
| 5 | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | 1 | 19 |
| 4 | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | ½ | 18 |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 21 |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | 1½ | 9 |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |

visualize the time involved. In general we realize that these successions require long periods of time and we would be ready to say at once that the length of time of periods would certainly be related to the suddenness and severity of environmental changes. In Table 3 we have attempted to indicate an approixmation of the time required after deposition began in each of the areas for the three forest dominants (Abies, Picea, and Quercus) to effect marked changes in forest composition. Computation of time was made by taking into consideration the number of foot-levels from the bottom where each change occurred. This makes it quite necessary that the real bottom of the bog be reached in all cases in the borings. We are certain of the bottom in every case by the fact that the deposits of marl or peat always lie on a sand or gravel bottom. The number of years allowed for each foot of deposit has been determined by the kind of deposit and the amount of overlying deposit as follows:

Each foot of marl is credited with 500 years.
Each foot of peat with 30-39 feet of overlying deposit, 400 years.
Each foot of peat with 20-29 feet of overlying deposit, 350 years.
Each foot of peat with 10-19 feet of overlying deposit, 300 years.
Each foot of peat with 1-9 feet of overlying deposit, 200 years.

**Ulmus**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | 5 | | | |
| 43 | | | | 6 | | | |
| 42 | | | | 10 | | | |
| 41 | | | | 10 | | | |
| 40 | | | | 9 | | | |
| 39 | | | | 14 | | | |
| 38 | | | | 8 | | | |
| 37 | | | | 2 | | | |
| 36 | | | | 7 | | | |
| 35 | | | | 4 | | | |
| 34 | | | | 4 | | | |
| 33 | | | | 8 | | | |
| 32 | 7 | 5 | | 7 | 3 | | |
| 31 | 4 | 7 | | 11 | 6 | | 10 |
| 30 | 2 | 5 | | 6 | 3 | | 8 |
| 29 | 3 | 6 | | 7 | 2 | 11 | 9 |
| 28 | 6 | 8 | 14 | 14 | 3 | 2 | 9 |
| 27 | 5 | 6 | 12 | 10 | 5 | 4 | 5 |
| 26 | 12 | 5 | 14 | 7 | 7 | | 8 |
| 25 | 16 | 9 | 5 | 3 | 6 | 3 | 7 |
| 24 | 10 | 6 | 6 | 8 | 8 | 4 | 10 |
| 23 | 14 | 8 | 7 | 11 | 13 | 6 | 11 |
| 22 | 17 | 10 | 11 | 10 | 12 | | 12 |
| 21 | 7 | 10 | 8 | 13 | 13 | 2 | 11 |
| 20 | 10 | 8 | 3 | 10 | 10 | 3 | 9 |
| 19 | 12 | 7 | 13 | 20 | 10 | 2 | 9 |
| 18 | 11 | 12 | 10 | 16 | 12 | 6 | |
| 17 | 4 | 8 | 13 | 25 | 16 | 6 | |
| 16 | 7 | 10 | 10 | 17 | 7 | 8 | |
| 15 | 6 | 12 | 8 | 18 | | 12 | |
| 14 | 1 | 8 | 4 | 19 | | 9 | |
| 13 | | 7 | 7 | 15 | | 14 | 15 |
| 12 | | 5 | 11 | ½ | | 12 | 1 |
| 11 | | 3 | 5 | | | 17 | |
| 10 | | 7 | 3 | | | 4 | |
| 9 | | | ½ | | | 15 | |
| 8 | | | ½ | | | 7 | |
| 7 | | | | | | 1½ | |
| 6 | | | | | | 1½ | |
| 5 | | | | | | | |
| 4 | | | | | | ½ | |
| 3 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |

**Salix**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | 3 | | | |
| 43 | | | | 1 | | | |
| 42 | | | | 8 | | | |
| 41 | | | | 5 | | | |
| 40 | | | | 2 | | | |
| 39 | | | | 8 | | | |
| 38 | | | | 6 | | | |
| 37 | | | | 6 | | | |
| 36 | | | | 5 | | | |
| 35 | | | | 10 | | | |
| 34 | | | | 7 | | | |
| 33 | | | | 9 | | | |
| 32 | 4 | 10 | | 10 | 5 | | |
| 31 | 2 | 8 | | 4 | 5 | | 5 |
| 30 | | 10 | | 5 | 2 | | 5 |
| 29 | 2 | 10 | | 14 | 5 | 7 | 4 |
| 28 | 2 | 11 | 10 | 4 | 2 | 6 | 4 |
| 27 | 3 | 13 | 4 | 13 | 1 | 8 | 4 |
| 26 | 3 | 10 | 4 | 6 | 1 | 8 | 3 |
| 25 | 4 | 10 | 12 | 7 | 2 | 5 | 5 |
| 24 | 2 | 6 | 4 | 5 | 1 | 1 | 5 |
| 23 | ½ | 6 | 8 | 12 | 3 | 3 | 4 |
| 22 | 1 | 5 | 4 | 4 | 2 | 8 | 3 |
| 21 | 3 | 8 | 6 | 8 | 2 | | 3 |
| 20 | 4 | | 7 | 9 | 3 | 12 | 4 |
| 19 | 5 | | 3 | 9 | 6 | | |
| 18 | 9 | | 3 | 6 | 5 | 3 | |
| 17 | 15 | | 5 | 4 | 3 | 1½ | |
| 16 | 18 | 17 | 6 | 4 | 5 | 1½ | |
| 15 | 16 | 18 | 7 | 17 | 7 | 2 | |
| 14 | 16 | 18 | 7 | 17 | 6 | 3½ | |
| 13 | 4 | 16 | 6 | 11 | 6 | 6½ | 1 |
| 12 | | | 13 | 21 | 6 | 6 | |
| 11 | 5 | 18 | 32 | 41 | 2 | 6 | 2 |
| 10 | 3 | 18 | 34 | 1 | | 2 | 3 |
| 9 | 1 | 30 | 17 | 2 | | 3½ | |
| 8 | 2 | 14 | 6 | 2 | | 4 | |
| 7 | 1 | 3 | 2 | | | ½ | |
| 6 | | | ½ | | | 4 | |
| 5 | | | ½ | | | | |
| 4 | | | | | | 1 | |
| 3 | | | | | | 1 | |
| 2 | | | | | | | |
| 1 | | | | | | | |

**Larix**

| Foot Level | B | C | F | O | K | M | L |
|---|---|---|---|---|---|---|---|
| 44 | | | | 1 | | | |
| 43 | | | | | | | |
| 42 | | | | | | | |
| 41 | | | | | | | |
| 40 | | | | 4 | | | |
| 39 | | | | 3 | | | |
| 38 | | | | 1 | | | |
| 37 | | | | 2 | | | |
| 36 | | | | 2 | | | |
| 35 | | | | 4 | | | |
| 34 | | | | 5 | | | |
| 33 | | | | 3 | | | |
| 32 | | | | 2 | | | |
| 31 | | | | 3 | | | 1 |
| 30 | 1 | | | 4 | | | 2 |
| 29 | 4 | | | 1 | | | ½ |
| 28 | | | | 2 | | | 1 |
| 27 | | | 1 | 3 | | | ½ |
| 26 | | | 1 | | | 10 | 1 |
| 25 | 1 | 2 | 2 | 1 | | 8 | 1 |
| 24 | 1 | | 2 | 3 | | | 3 |
| 23 | 1 | | 5 | 2 | | | 1 |
| 22 | 2 | | 5 | 3 | | 2 | 5 |
| 21 | 15 | | 6 | 2 | | 6 | 5 |
| 20 | 19 | | 11 | 2 | | 3 | ½ |
| 19 | 21 | 2 | 14 | 5 | | | 4 |
| 18 | 29 | 4 | 18 | 3 | | ½ | |
| 17 | 32 | 2 | 10 | 1 | 5 | 1½ | |
| 16 | 19 | 6 | 9 | 4 | 12 | 2 | |
| 15 | 18 | 7 | 19 | ½ | 12 | | |
| 14 | 14 | 11 | 22 | 1 | 14 | ½ | |
| 13 | 10 | 15 | 29 | 4 | 8 | 1 | 4 |
| 12 | 3 | 19 | 23 | 8 | 28 | 2½ | 1 |
| 11 | 2 | 15 | 16 | 7 | 2 | | 1 |
| 10 | 3 | 25 | 19 | 1 | 14 | ½ | 1 |
| 9 | | 19 | 12 | 1 | 2 | ½ | ½ |
| 8 | | 12 | 5 | 5 | 4 | 3 | 1 |
| 7 | | 2 | 4 | 2 | | 14½ | 2 |
| 6 | | | 1 | 5 | | 42 | 1 |
| 5 | ½ | 2 | 1 | 1 | | 10 | 3 |
| 4 | ½ | | | | | 6 | ½ |
| 3 | ½ | | | | | | |
| 2 | ½ | | | | | | 1 |
| 1 | | | | | | ½ | |

From such a study we find that: (1) Abies lost importance as a component of the forest in the different areas studied from 2050 to 6000 years and completely disappeared from 3750 to 8400 years after deposition began. (2) Picea lost importance as a component of the forest from 1000 to 6600 years completely disappeared from 5400 to 14,900 years after deposition began. (3) Quercus made its appearance from 1000 to 5500 years and became the dominant forest component from 1700 to 6900 years after deposition began. It is thus seen that the time of Quercus dominance closely corresponds to the time of loss of importance by Abies and Picea. There seemes to be little relation between the latitude of the areas here studied and the time after deposition began when the significant forest changes occurred.

Pinus formed an important element of the forest only in the Lake Cicott area where it was the forest dominant following loss of dominance by Abies and prior to gain of dominance by Quercus. Pinus thus occupied in the Lake Cicott area the position held by Picea in all of the other areas in this study. While Pinus did not form an important component of the post-glacial forest (except in Lake Cicott area) it nevertheless held on tenaciously as a relic to the very top layer of the peat but it had disappeared when civilized man moved into the region. It still persists as a relic in a few locations in the state.

Betula, Ulmus, Larix, and Salix apparently reached their maximum of representation after the decline of Abies and Picea and the dominance of Pinus and Quercus. (Table 1).

TABLE 2. Plant succession as revealed from study of 7 bogs. The foot-levels at which changes occurred are given on the left. The dominants are enclosed in parentheses.

**Bacon's Swamp**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | (Abies) | Picea | | — | — | — | — | — | — | — | — |
| 2. | (Abies) | Picea | Larix | — | — | — | — | — | — | — | — |
| 4. | (Abies) | Picea | Larix | Pinus | — | — | — | — | — | — | — |
| 7. | Abies | (Picea) | — | Pinus | Salix | — | — | — | — | — | — |
| 9. | Abies | (Picea) | — | Pinus | Salix | Quercus | — | — | — | — | — |
| 10. | Abies | (Picea) | Larix | Pinus | Salix | Quercus | Carya | Betula | — | — | — |
| 14. | Abies | (Picea) | Larix | Pinus | Salix | Quercus | Carya | Betula | Ulmus | — | — |
| 19. | Abies | Picea | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 22. | — | Picea | Larix | Pinus | Salix | (Quercus) | (Carya) | — | Ulmus | Acer | — |
| 23. | — | — | Larix | Pinus | Salix | (Quercus) | (Carya) | Betula | Ulmus | Acer | — |
| 24. | — | — | Larix | Pinus | Salix | (Quercus) | (Carya) | — | Ulmus | Acer | — |
| 25. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | — | Ulmus | Acer | Fagus |
| 26. | — | — | — | Pinus | Salix | (Quercus) | Carya | — | Ulmus | Acer | Fagus |
| 29. | — | — | Larix | Pinus | — | (Quercus) | Carya | — | Ulmus | (Acer) | Fagus |
| 31. | — | — | — | Pinus | Salix | (Quercus) | Carya | — | Ulmus | (Acer) | Fagus |
| Top. | — | — | — | — | Salix | Quercus | Carya | — | Ulmus | Acer | Fagus |

**Otterbein**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | (Abies) | Picea | — | — | — | — | — | — | — | — | — |
| 2. | (Abies) | Picea | — | Pinus | — | — | — | — | — | — | — |
| 5. | (Abies) | Picea | Larix | Pinus | — | — | — | — | — | — | — |
| 7. | Abies | (Picea) | Larix | Pinus | — | Quercus | — | — | — | — | — |
| 8. | (Abies) | (Picea) | Larix | Pinus | Salix | Quercus | — | Betula | — | — | — |
| 12. | Abies | Picea | Larix | Pinus | Salix | (Quercus) | — | Betula | Ulmus | — | — |
| 13. | Abies | Picea | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | — | — |
| 14. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | — | — |
| 16. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 40. | — | — | — | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 44. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| Top. | — | — | — | — | Salix | Quercus | Carya | — | Ulmus | Acer | — |

**Kokomo**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | (Abies) | Picea | | Pinus | — | — | — | — | — | — | — |
| 8. | Abies | (Picea) | Larix | Pinus | — | — | — | — | — | — | — |
| 11. | Abies | (Picea) | Larix | Pinus | Salix | Quercus | — | Betula | — | — | — |
| 14. | Abies | Picea | Larix | Pinus | Salix | (Quercus) | — | Betula | — | Acer | — |
| 15. | — | Picea | Larix | Pinus | Salix | (Quercus) | Carya | Betula | — | Acer | — |
| 16. | — | Picea | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 17. | — | Picea | — | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 20. | — | Picea | — | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | Fagus |
| 27. | — | — | — | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | Fagus |
| 32. | — | — | — | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | Fagus |
| Top. | — | — | — | — | Salix | Quercus | Carya | Betula | Ulmus | Acer | Fagus |

**Lake Cicott**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | (Abies) | Picea | — | Pinus | — | — | — | Betula | — | — | — |
| 2. | (Abies) | Picea | Larix | Pinus | — | Quercus | — | Betula | — | — | — |
| 10. | Abies | Picea | Larix | (Pinus) | Salix | Quercus | — | Betula | — | — | — |
| 11. | Abies | Picea | Larix | (Pinus) | Salix | Quercus | Carya | Betula | — | — | — |
| 12. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | — | — |
| 13. | — | Picea | Larix | Pinus | Salix | Quercus | Carya | Betula | Ulmus | — | — |
| 19. | — | Picea | Larix | Pinus | — | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 20. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 23. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | — | Ulmus | Acer | — |
| 25. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | Fagus |
| 27. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | — | Ulmus | Acer | Fagus |
| 28. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer | — |
| 30. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | — | Ulmus | Acer | — |
| 31. | — | — | Larix | Pinus | Salix | (Quercus) | Carya | — | Ulmus | Acer | — |
| Top. | — | — | — | — | Salix | Quercus | Carya | — | Ulmus | Acer | — |

Matthews 17

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | (Abies) | (Picea) | Larix | Pinus | | | | | | |
| 2. | Abies | (Picea) | | Pinus | | Quercus | | Betula | | |
| 3. | Abies | (Picea) | | Pinus | Salix | Quercus | | | | |
| 4. | Abies | (Picea) | Larix | Pinus | Salix | Quercus | | Betula | Ulmus | |
| 5. | Abies | (Picea) | Larix | | | Quercus | | Betula | | |
| 6. | Abies | (Picea) | (Larix) | Pinus | Salix | Quercus | | Betula | Ulmus | |
| 9. | | | Larix | Pinus | Salix | (Quercus) | | Betula | Ulmus | |
| 10. | | Picea | Larix | | Salix | (Quercus) | Carya | Betula | Ulmus | |
| 11. | | Picea | | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | |
| 12. | | Picea | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer |
| 13. | | | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | |
| 14. | | | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer |
| 15. | | | | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | |
| 16. | | | Larix | | Salix | (Quercus) | Carya | Betula | Ulmus | Acer |
| 18. | | | Larix | Pinus | Salix | (Quercus) | Carya | | Ulmus | Acer |
| 19. | | | | Pinus | | (Quercus) | Carya | | Ulmus | Acer |
| 20. | | | Larix | Pinus | Salix | (Quercus) | Carya | | Ulmus | Acer |
| 21. | | Picea | Larix | Pinus | | (Quercus) | Carya | Betula | Ulmus | Acer |
| 22. | | Picea | Larix | Pinus | Salix | (Quercus) | Carya | | | |
| 23. | | Picea | | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | Acer |
| 24. | | | | Pinus | Salix | (Quercus) | Carya | | Ulmus | Acer |
| 25. | | | Larix | | Salix | (Quercus) | Carya | | Ulmus | Acer |
| 26. | | Picea | Larix | Pinus | Salix | (Quercus) | Carya | | Ulmus | |
| 27. | | | | Pinus | Salix | (Quercus) | Carya | Betula | | Acer |
| 28. | | Picea | | | Salix | (Quercus) | Carya | | Ulmus | Acer |
| 29. | | Picea | | Pinus | Salix | (Quercus) | | | Ulmus | Acer |
| 30. | | | | | Salix | Quercus | Carya | | Ulmus | Acer |

Cranberry Pond - Emporia

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | (Abies) | Picea | | Pinus | | | | | | | |
| 4. | (Abies) | Picea | | Pinus | | | | Betula | | | |
| 5. | (Abies) | Picea | Larix | Pinus | | | | Betula | | | |
| 7. | (Abies) | (Picea) | Larix | Pinus | Salix | Quercus | | Betula | | | |
| 10. | Abies | Picea | (Larix) | Pinus | Salix | (Quercus) | | Betula | Ulmus | | Fagus |
| 12. | Abies | Picea | (Larix) | Pinus | | (Quercus) | Carya | Betula | Ulmus | | Fagus |
| 13. | Abies | Picea | Larix | (Pinus) | Salix | (Quercus) | | Betula | Ulmus | | |
| 15. | Abies | | Larix | Pinus | Salix | (Quercus) | Carya | Betula | Ulmus | | |
| 17. | | | Larix | Pinus | | (Quercus) | Carya | Betula | Ulmus | | Fagus |
| 20. | | | | Pinus | | (Quercus) | (Carya) | Betula | Ulmus | Acer | Fagus |
| 21. | | | | Pinus | Salix | (Quercus) | (Carya) | Betula | Ulmus | | Fagus |
| 22. | | | | Pinus | Salix | (Quercus) | (Carya) | Betula | Ulmus | Acer | Fagus |
| 25. | | | Larix | Pinus | Salix | (Quercus) | (Carya) | | Ulmus | Acer | Fagus |
| 26. | | | | Pinus | Salix | (Quercus) | (Carya) | Betula | Ulmus | Acer | Fagus |
| 28. | | | | Pinus | Salix | (Quercus) | (Carya) | Betula | Ulmus | | Fagus |
| 32. | | | | Pinus | Salix | (Quercus) | (Carya) | Betula | Ulmus | | Fagus |
| Top. | | | | | Salix | Quercus | Carya | Betula | Ulmus | | Fagus |

## Relic Colonies

From a study of pollen remains in peat bogs we have seen that forests change only slowly and over long periods of time as the result of migration of species. We have also seen that long after a migrating species has lost importance as a component of the forest it may remain in gradually reducing numbers before it finally disappears. Its ultimate disappearance from a larger area is often, perhaps always, marked by a time period during which the species persists as a relic only in isolated areas where local environment is sufficiently favorable to permit it to survive in competition with the invading species. It has been shown (Friesner and Potzger, 1932a, b, 1936; Potzger and Friesner, 1936) that the environment occupied by relic forms is more rigorous than that only a few feet away occupied by invaders. That the state

TABLE 3. The horizon and the time after deposition began when Abies, Picea and Quercus effected marked changes in forest composition. The horizon is given in terms of feet of deposits from the bottom upward. Determination of time in years is described in the text.

| | Abies | | Picea | | Quercus | |
|---|---|---|---|---|---|---|
| | Lost Importance | Disappeared | Lost Importance | Disappeared | Appeared | Gained Importance |
| Bacon's Swamp | 10* + 3 ft.<br>6000 yrs. | 10 + 11 ft.<br>8400 yrs. | 10 + 5 ft.<br>6600 yrs. | 10 + 12 ft.<br>8700 yrs. | 9 + 0 ft.<br>4500 yrs. | 10 + 6 ft.<br>6900 yrs. |
| Cranberry Pond | 2 + 7<br>3450 | 2 + 15<br>6000 | 2 + 6<br>3100 | 2 + 13<br>5400 | 2 + 5<br>2750 | 2 + 8<br>3800 |
| Fox Prairie | 9 + 0<br>4500 | 11 + 7<br>8050 | 10 + 0<br>5000 | 11 + 8<br>8400 | 6 + 0<br>3000 | 11 + 0<br>5500 |
| Otterbein | 11 + 0<br>5500 | 14 + 2<br>7750 | 11 + 0<br>5500 | 14 + 27<br>14,900 | 7 + 0<br>3500 | 11 + 0<br>5500 |
| Kokomo | 12 + 0<br>6000 | 12 + 3<br>6900 | 12 + 0<br>6000 | 12 + 15<br>10,000 | 11 + 0<br>5500 | 12 + 0<br>6000 |
| Matthews | 4 + 4<br>3400 | 4 + 5<br>3750 | 4 + 4<br>3400 | 4 + 25<br>8750 | 2 + 0<br>1000 | 4 + 2<br>2700 |
| Lake Cicott | 2 + 3<br>2050 | 2 + 10<br>4450 | 2 + 0<br>1000 | 2 + 18<br>6850 | 2 + 0<br>1000 | 2 + 2<br>1700 |

* The first given is marl, the second peat.

has been the scene of intense vegetational struggle (Friesner, 1937) is shown by the fact that relic colonies of over fifty species of plants today characteristic of more northern areas, are to be found within the state.

Habitats for relic colonies of trees in Indiana are of two types, viz. bogs and rocky cliffs. Of the cliff type, the colonies at Trevlac, Brown County and Pine Hills, Montgomery County have been studied in detail (Friesner and Potzger, 1932, 1934, 1936), while Daubenmire (1931) made a similar study of the relic colony at Turkey Run in Parke County. The relic colonies in bogs have been discussed earlier in this paper. *Pinus strobus* once probably widely distributed over the state as indicated by fossil pollen, is at present limited to seven stations (Welch, 1936). It seems to hold its own in the colony at Pine Hills but it displays even there no evidence of dynamic expansion of territory. So, even in an area where it is at its best, white pine is merely marking time, and indicates plainly that it needs a protecting hand to preserve it as a part of the vegetation. The same must certainly be said of Tsuga at Trevlac and at Pine Hills and Turkey Run.

A few of the static shrub colonies are *Taxus canadensis,* found at three stations, Putnam, Parke and Montgomery Counties, all rocky cliffs. At none of these places is Taxus invading the broad-leaved forest as it does so characteristically in northern Michigan (Potzger, Ms.). *Cornus rugosa* is still present in the northern tiers of counties but to the south it is found only at Pine Hills, Montgomery County. *Gaultheria procumbens* occurs in the northern two tiers of counties and then has three scattered colonies which

extend its relic range to the Ohio River. *Diervilla lonicera* occurs in the two tiers of counties south of the dunes of Lake Michigan and then in disjunct colonies in Fountain county, at Pine Hills in Montgomery county and in Steuben county, while its mass distribution is northward with a fringe southward in the eastern mountains. The striking feature of present-day distribution on the rear fringe of a migrating vegetation is these disjunct colonies which extend into and make up the fringe. All of these small colonies have become mere curiosities in a climatic climax where they are out of place as a dynamic entity of the vegetation, they are merely tolerated by aid of microclimate and removal of this aid eliminates them from the vegetation and straightens the southern line of the boreal forest complex whose sweeping general belt has already advanced northward beyond the borders of Indiana.

## Discussion

Many of the phenomena associated with climatic changes and movements of forests are frequently a long time process, at least in terms of human life. We can recognize explosive catastrophic processes much more readily and accurately than gradual transition where the loss of a tree without compensated reproduction means a slow but definite change of vegetation type. In the northern border of the great vegetation belt of the boreal forest advances even of single individuals are more emphatic as indicators of change because there is not the obscuring influence of competing vegetation masses as in the southern border. Yet we must expect the nature of the process to be more or less similar except that for boreal species the end results mean retreat at the southern border.

What information can we gain from the pollen spectra of these regions in regard to the nature of the process and the time element involved in the advance of forests? The record of a type of forest similar to that of Alaska today, limited to a few species (Abies and Picea) is clearly shown in the lower strata of all of the seven bogs listed here. In all bogs is indicated a "sudden" decline of dominance by Abies and Picea and a compensating crowding in of deciduous genera. But when we speak of "sudden decline" we speak in terms and impressions gained from a highly compressed time scale indicated by feet and inches of peat accumulations, and our eye is apt to make us disregard the real passing of time. How long does it take to accumulate four or five feet of peat or marl? Opinions differ. Sears (1932) suggests 300 years to a foot accumulation, but Soper and Osborn (as quoted by Sears) computed a much slower time scale, i.e. 0.72 to 2.16 inches in a century, and this is considered by them a rapid accumulation. It is apparent that peat from the upper and lower levels of a bog profile represent different lengths of time of accumulation, for the lower levels are compressed by the weight of the upper layers.

Considering, then, the few inches in which Abies and Picea constituted almost the total vegetation of the region about the southern limits of Wisconsin glaciation in Indiana, thousands of years must have passed before the first broad-leaved species invaded, and for thousands of years they made only

a slow progress. No doubt it would have been a much more difficult problem for an investigator, if one could have worked here in present Indiana at that time, to sift out the true nature of the advance, than for a worker in fossil pollen today with events "focussed under oil immersion."

Comparing with these static records of the bogs the dynamic records gathered by Cooper (1923, 1931) and Griggs (1914, 1934) we must probably say that advance could not have been faster in early post glacial times than now. Judging from the wide valleys of such now insignificant Indiana streams as White River, Salt Creek and Fall Creek, all of the soil water must have been affected by the cold waters from the melting ice.

The path of Pinus, Larix, Thuja would have been still more difficult to observe during the retreat, for they persisted as relic groups in an area between Indianapolis and Logansport to a time in which the last foot of peat accumulated in the bogs, (Table 1) but had disappeared entirely when civilized man moved into Indiana a century ago. This retreat, thus, took place within the last few centuries and is doubly significant if we consider that the process was not modified by cultural influences which change habitats catastrophically.

Griggs (1934) and others wondered what controlled the sharp line between the forest edge and the unoccupied open spaces to the north of the boreal forest in Alaska. They say it cannot be the climatic temperature for it is quite evident that the climate of Alaska could support forests. Could the control not be sought in the lack of proper soil organisms for the development of mycorrhiza on the roots of invading trees? We well recall what a difficult time the farmers of the Middle West had to get a good stand of alfalfa until the cooperating microorganisms were introduced. It seems very logical that it would require a long time to prepare soil sufficiently for proper relationships between forest and microorganisms.

The pollen spectra show a more decisive and culminating decline for Abies and Picea than for any other genera (Table 1) which no doubt indicates that in the earlier post-glacial centuries some simple environmental factor, probably temperature, favored these genera and retarded the advance of the invaders. Evidently soil warmed up rather rapidly after the cold winds and waters from the retreating ice masses were removed by further ice retreat. This must have been true especially along the edges of streams and in bogs.

All of the remaining boreal vegetation still existing in Indiana is in a critically balanced position, merely existing in small circumscribed areas controlled by microclimate. In fact, the conditions at the Merrillville bog are almost a duplicate of the picture portrayed by the pollen spectrum from Lake Cicott bog. Lindsey says, "*Pinus strobus* is the important tree at present but it is doomed to yield its position to the incoming oaks. A pine seedling is rarely found on the forest floor, while oak seedlings are most common, *thus indicating that the pines are yielding to an oak succession.*" The relic colonies of boreal plants in Indiana today are a reflection of the condition indicated by spruce, fir and pine in the pollen spectrum several hundred or thousands of years ago. The least disturbance of the habitat by drainage or fire eliminates them forever from the vegetation complex. Indicators of this are the

extensive fossil remains in the Blue River valley as reported by Potzger (1939) and the cranberries in Cranberry Pond as reported by Barnett (1937).

*Pinus strobus, Tsuga canadensis, Taxus canadensis, and Thuja occidentalis* in all the relic colonies where they persist are plainly marking time and only protection can hold them. It is largely a question of length of life of the large trees, and each tree eliminated means a further retreat of the boreal forest. This is directly comparable with the process of advance in the north where pioneers invade in small numbers. In the north isolated trees advance the line of the boreal forest while on the southern border trees are eliminated one by one with the significance that the broad leaved forest is pushing northward the border of the boreal forest.

The present-day strangle-hold of the broad-leaved forest and gradual elimination of individuals with a check on reproduction and expansion of boreal species is excellently mirrored in this study. The two forest formations could well be compared to our so-called Lake Forest whose apex trails off in isolated outposts of the deciduous forest in the north and whose other apex to the south trails off in relic colonies in the great mass of the broad-leaved species.

In the belt of 150 miles from the border of Early Wisconsin glaciation in Indiana to the border of Michigan, the rear-guards of the boreal forest are apparently making a last losing stand in small relic colonies against a climatically-favored dynamic deciduous forest.

## Summary

1. A comparison is made between the advance of the boreal forest along its northern border in Alaska and the comparable retreat along its southern border of the Early Wisconsin glaciation in Indiana.

2. Relic colonies, fossil logs and fossil pollen from seven bogs are cited as evidences.

3. Evidence from fossil pollen indicates that migration resulted in changing the post-glacial forests of Indiana from boreal to a more temperate broad-leaved forest.

4. The advance of the broad-leaved genera was coincident with the retreat of the boreal genera.

5. Dominance by boreal genera was maintained for a few thousand years after the retreat of the glaciers.

6. Loss of dominance by the boreal species occurred relatively suddenly, i.e. over a period of a few hundred years.

7. In all cases the boreal elements of the forest held on as relics for many centuries after loss of dominance and in the case of Pinus, Larix, and Thuja (and in some areas Picea also) persisted to within a few hundred years of the time of settlement of the land by white man.

8. Boreal species still present in Indiana are dependent on microclimate

to persist in small isolated colonies. Nowhere in Indiana do these species make aggressive advances.

9. Boreal relics persisting in Indiana (*Pinus strobus,* Thuja, Larix) indicate that they are following a path of extinction similar to that followed by the same genera in bogs where they had become extinct comparatively shortly before the appearance of civilized man.

10. Some boreal relics have disappeared from Indiana since the time of occupancy by civilized man. Comparatively slight modifications of the habitat eliminated them.

11. The slow process of contraction of the boreal forest on its southern fringe during post-glacial time is not unlike that of its expansion on its northern fringe in Alaska, in reverse order.

## REFERENCES


BARNETT, JEAN PAUL. 1937.—Pollen study of Cranberry Pond near Emporia, Madison County, Indiana. Butler Univ. Bot. Stud. **4**:55-64.

BERRY, EDWARD WILBER. 1932—Tree Ancestors. Williams and Wilkins Company Baltimore.

BRAUN, E. LUCY. 1935—The undifferentiated deciduous forest climax and the association-segregate. Ecology **16**:514-518.

BROWN, CLAIR A. 1938—The flora of Pleistocene deposits in the western Florida Parishes, West Feliciana Parish, and East Baton Rouge Parish, Louisiana. Department of Conservation, Louisiana Geological Survey, Geological Bul. 12.

COOPER, WM. S. 1923—The recent ecological history of Glacier Bay, Alaska. Ecology **4**:93-128; 223-246; 355-365.

———1931—Third expedition to Glacier Bay, Alaska. Ecology **12**:61-95.

DAUBENMIRE, REXFORD F. 1931—Factors favoring the persistence of a relic association of eastern hemlock in Indiana. Butler Univ. Bot. Stud. **2**:29-32.

FRIESNER, RAY C. 1937—Indiana as a critical botanical area. Proc. Indiana Acad. Sci. 46:28-45.

FRIESNER, RAY C. AND J. E. POTZGER. 1932—Studies in forest ecology. I. Factors concerned with hemlock reproduction in Indiana. II. The ecological signficance of *Tsuga canadensis* in Indiana. Butler Univ. Bot. Stud. **2**:133-149.

———1934—Climax conditions and ecological status of *Pinus strobus, Taxus canadensis* and *Tsuga canadensis* in the Pine Hills region of Indiana. Butler Univ. Bot. Stud. **3**:65-83.

———1936—Soil moisture and the nature of the Tsuga and Tsuga-Pinus forest associations in Indiana. Butler Univ. Bot. Stud. **3**:207-209.

GRIGGS, ROBERT F. 1914—Observations on the edge of the forest in the Kodiak region of Alaska. Bull. Torr. Bot. Club **41**:381-385.

———1934—The edge of the forest in Alaska and the reasons for its position. Ecology **15**:80-96.

HANNA, G. DALLAS. 1933—Diatoms of the Florida peat deposits. Florida Geol. Survey twenty-third to twenty-fourth Ann. Rep.

HOWELL, JOHN W. 1938—A fossil pollen study of Kokomo Bog, Howard County, Indiana. Butler Univ. Bot. Stud. **4**:117-127.

HUNTINGTON, ELLSWORTH AND S. S. VISHER. 1922—Climatic Changes. Yale University Press.

LINDSEY, ALVA J. 1932—The Merrillville white pine bog, Lake County, Indiana. Butler Univ. Bot. Stud. **2**:167-178.

MARKLE, M. S. 1915—Phytoecology of peat bogs near Richmond, Indiana. Proc. Indiana Acad. Sci. **25**:359-375.

OTTO, JAMES H. 1938—Forest succession in the southern limits of early Wisconsin glaciation as indicated by a pollen spectrum from Bacon's Swamp, Marion County, Indiana. Butler Univ. Bot. Stud. **4**:93-115.

POTZGER, J. E. 1936—Post Pleistocene fossil records in peat of the upper Blue River in Henry County, Indiana. Proc. Indiana Acad. Sci. **45**:64-68.

———1939—Microclimate and a notable case of its influence on a ridge in Central Indiana. Ecology **20**:29-37.

———1938—Some acidity studies in dunes and bogs. Proc. Indiana Acad. Sci. **47**:100-105.

———Vegetation of Mackinac Island, Michigan: An ecological survey. (Ms.)

POTZGER, J. E. AND R. C. FRIESNER. 1937—Soil acidity and hemlock reproduction in relic colonies in Indiana. Proc. Indiana Acad. Sci. **46**:93-99.

PRETTYMAN, ROBERT L. 1937—Fossil pollen analysis of Fox Prairie Bog, Hamilton County, Indiana. Butler Univ. Bot. Stud. **4**:33-42.

RICHARDS, RUTH R. 1938—A pollen profile of Otterbein Bog, Warren County, Indiana. Butler Univ. Bot. Stud. **4**:128-140.

SEARS, PAUL B. 1932—Postglacial climate in eastern North America. Ecology **13**:1-6.

SMITH, WILLIAM M. 1937—Pollen spectrum of Lake Cicott bog, Cass County, Indiana. Butler Univ. Bot. Stud. **4**:43-54.

STEERE, WILLIAM C. 1938—Pleistocene mosses from Louisiana Department of Conservation, Louisiana Geol. Survey Geol. Bul. 12.

THWAITES, E. T. 1937—Outline of glacial geology. Edwards Bros. Inc., Ann Arbor, Michigan.

WELCH, WINONA H. 1936—Boreal plant relics in Indiana. Proc. Indiana Acad. Sci. **45**:78-88.

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# A Phytosociological Study of a Nyssa biflora Consocies in Southeastern Louisiana

Thomas F. Hall and William T. Penfound

## Introduction

Swamp forests including bald cypress, *Taxodium distichum,* tupelo gum, *Nyssa aquatica* and swamp black gum, *Nyssa biflora* are common throughout the Southeastern United States. These forests may be composed of any of these species in pure stand or in any conceivable combination. In addition slash pine, *Pinus Caribaea,* and the 'so-called' pond cypress, *Taxodium ascendens,* may be important components in shallow, swampy areas throughout the lowlying flat pinelands of the lower Coastal Plain.

The black gum swamp is a variant of cover type number 92 of the Society of American Foresters. It is confined to ponds and sloughs of acid pinelands and to the deltas of streams which flow through them. It often consists of the swamp black gum, *Nyssa biflora,* in pure stand, although tupelo gum and bald cypress, may be associated with it. A mixed stand including all three species has been studied at Indian Village on West Pearl River. The investigation herein reported was conducted on a practically pure stand of the swamp black gum situated on Gum Creek about ¾ miles above its junction with Old River, one of the many branches of Pearl River. It is approximately 0.6 miles west of the town of Pearl River, La., and is readily accessible by car (Fig. 1).

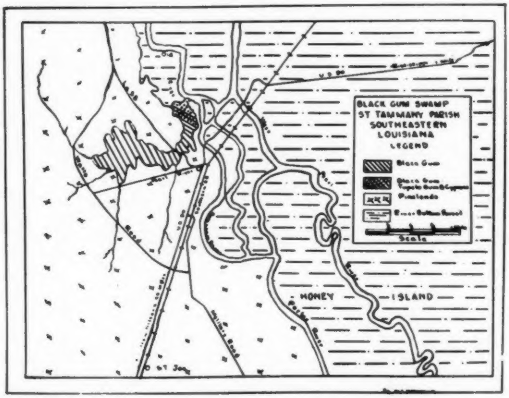



Fig. 1. The black gum swamp is located in Gum Creek at the edge of the Pearl River Valley in Southeastern Louisiana.

## Description

The sample of the black gum swamp studied is rather forbidding in appearance. The trees are numerous, tall, and cast a dense shade over the black water or mud of the nearly barren forest floor. The swollen bases of the trunks are covered with a dark mantle of liverworts and mosses and several of the trunks bear large fantastic galls. These features, together with the tangle of looping roots which spreads over the soil surface, gives the forest a weird but compelling aspect (Fig. 2). Curiously enough there is little Spanish moss and only an occasional mistletoe in the swamp although they are abundant in nearby forests. In this swamp also the trees almost always grow singly whereas the swamp black gum trees in a neighboring swamp (Indian Village) are often fused together in groups of two to four to form "stools."

Fig. 2. The trees of the black gum swamp are numerous, tall and possess characteristic swollen bases as well as looping roots.

In this black gum swamp the trees were relatively slender except for the very conspicuous, enlarged bases (Fig. 2). These bases average 10 (8 to 13) feet in height with an average diameter at breast height of 25.7 inches. At the height of 10 feet where the swollen base merges into the normal trunk the average diameter is only 14.5 inches. The trees average 83 (75 to 89) feet in height with a probable age of 200 years. This age is only an approximation since no entirely solid trees were found on which to make total ring counts.

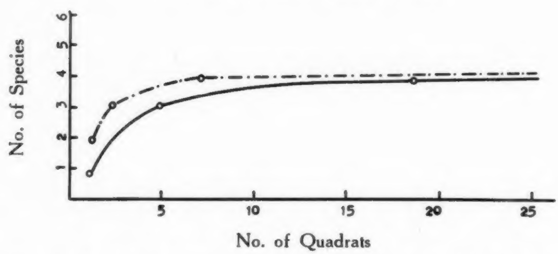
The black gum swamp forest is the simplest arborescent phytocoenosis observed by the writers. It consists of an excellent arborescent synusia but no others except the bryological synusiae on the tree trunks. The community includes a total of only fourteen species and of these species only the swamp black gum is an important component. It is estimated that the aggregate coverage of all species other than the swamp black gum would not be more than two percent. In a study of the red maple swamp forest on Long Island, Cain and Penfound (1938) designated six phanerogamic synusiae. Of these synusiae one was arborescent, two were frutescent, and three were herbaceous In the well-developed black gum forest, however, the frutescent and herbaceous communities are absent.

## Phytosociological Analysis

The arborescent synusia was sampled by 25 consecutive quadrats of 100 square meters (approximately 1/40 acre) each. Only four arborescent species were sampled, and of these the swamp black gum was all important (Fig. 3). There were 302 living trees and 34 dead trees per acre. As based on the swollen butts of the trees, the basal area reached the astounding figure of 1095 square feet per acre. Even when based on the normal trunk diameter, 10 feet above the ground level, the basal area was much higher than is usually found (338 square feet per acre). This is due to the relatively great number of trees per acre in this stand. The basal area of the other three woody species sampled in the quadrats is insignificant since the average stem diameter was less than 2 inches and the frequency and density were relatively low. The frequency percentage for the swamp black gum, *Nyssa biflora,* was 100, for the bald cypress, *Taxodium distichum* (all seedlings) it was 10, and for the titi, *Cyrilla racemiflora* and the mayhaw, *Crataegus aestivalis* it was only 5 each. Three relatively conspicuous epiphytes were present in this swamp. The polypody fern, *Polypodium polypodioides,* was occasionally found on the larger horizontal branches; the green-fly orchid, *Amphiglottis conopsea,* was observed on the swollen bases and the spanish moss, *Dendropogon usneoides,* was to be seen occasionally among the upper branches of swamp black gum trees.

Despite the fact that there was no evident herbaceous synusia, it was decided to gain some conception of the herbaceous population by means of quadrats. Accordingly 25 quadrats of one square meter each and spaced arbitrarily at 5 meters apart were studied with the following results (Fig. 3).

SPECIES NUMBER: AREA CURVES




o—.—o Herbs and woody species less than 1 inch d.b.h. (1 M2 quadrats).
o———o Woody species greater than 1 inch d.b.h. (1/40 acre quadrats).

Fig. 3. A total of eight species only were encountered in the quadrat study of the black gum swamp.

Four species only were sampled and of these *Carex glaucescens* (the only herb) possessed both the highest frequency and the greatest coverage. A frequency percentage as high as 66 would suggest a reasonably high coverage. However, in the case of this species the coverage was estimated at about one per cent. Since this species possesses many times the coverage of any of the other species sampled the total coverage is probably less than two per cent. These figures indicate the great discrepancy between frequency and coverage data and suggests that frequency data be used with great discretion.

## PHENOLOGY

Growth is well under way in the deciduous forest of the valleys of the lower Coastal Plain by February 1. In the low pineland ponds the swamp black gum was in leaf by March 1 but in the dense swamp studied they were not in full leaf until March 15. This is probably due to the relatively cold water in the swamp at this time. Flowering is initiated about the middle of March and is completed by April 15. Young seedlings of both swamp black gum and cypress were noted on May 21, 1938 but the exact dates of germination are not known.

## PHYSICAL FACTORS

Undoubtedly the most important factor connected with the vegetation of this particular forest is the amplitude in water level throughout the year. Although the swamp is fed by springs the water in the swamp during the summer and autumn is usually confined to the shallow meandering channel. From January to June, however, water usually covers the forest floor to a depth of one to several feet, due to the backwater from Old River. An examination of Fig. 4 indicates this graphically. It should be pointed out,

however, that the depth of 12 feet that occurred in April of 1938 was the highest recorded in this swamp during the last 15 years. The relatively great height (10 feet) of the swollen bases is due to the deep water in the early part of the growing season. The swollen base is usually a measure of the height of the water during the growing season and is supposedly caused by aerated water (Kurz and Demaree, 1934). The markers at the top of the *Porella* belt in Figure 2 are six feet above the forest floor but the water in the swamp may be seven feet deep or more as is indicated by the pollen lines in Fig. 5. The absence of shrubby and herbaceous plants is correlated also with amplitude to some extent although the combination of dense shade and surface water are factors of greater importance.

## SOIL WATER

The amount of soil water was determined when the soil surface was covered with approximately twelve inches of water. Samples at depths of one, two, three, and four feet were taken at three stations in the swamp. It was found that the water content (as based on dry weight of the soil) decreased with depth.

| Depth (feet) | Per Cent Water in Soils | | | |
|---|---|---|---|---|
| | Sta. 1 | Sta. 2 | Sta. 3 | Ave. |
| 1 | 482 | 471 | 448 | 417 |
| 2 | 432 | 428 | 373 | 411 |
| 3 | 460 | 429 | 312 | 400 |
| 4 | 109 | 126 | 131 | 122 |

At the one foot level the amount of water was 4.67 times the oven-dry weight of the soil (4.48 to 4.82) but had decreased to 1.22 at the four foot level. The considerable decrease in per cent of water at the four foot level is due to the fact that little organic matter is present. Furthermore, the soil at this level contained more sand than the upper three feet of soil.

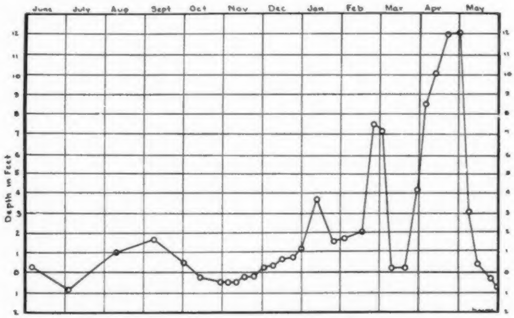



Fig. 4. The water level in the swamp varies as much as thirteen feet in a single year.

Fig. 5. The pollen lines on the trunk indicate the water level that was reached in March, 1939.

LOSS BY COMBUSTION

After determining the water content of the soils, each sample was incinerated over a bunsen burner until constant weight was obtained. Regarding loss by combustion it will be observed that the order was exactly the same as in the case of water content, with a gradual decrease to the three foot level and a sudden drop to the four foot level.

| Depth (feet) | Per Cent Loss by Combustion | | | |
|---|---|---|---|---|
| | Sta. 1 | Sta. 2 | Sta. 3 | Ave. |
| 1 | 51 | 53 | 47 | 50 |
| 2 | 49 | 46 | 44 | 46 |
| 3 | 48 | 47 | 39 | 45 |
| 4 | 11 | 9 | 12 | 11 |

As pointed out by Penfound and Hathaway (1938) the loss by combustion of saturated soils is approximately 10% of the water content. In the Pearl River Swamp this loss was approximately 11% in the soil samples taken at the one-, two-, and three-foot levels but only 9% in that of the lowest sample obtained. In general, however, these data conform closely to those obtained by the above authors.

HYDROGEN ION CONCENTRATION

Sixteen soil samples at four stations at depths of one to four feet were tested for acidity with a colorimetric set. As was expected the soil was quite acid (pH 5.1 to 5.3) but there was no correlation with station or with depth.

From these data it is probable that acidity plays little part in the distribution of vegetation in this swamp.

## Biotic Factors

To date man has not been an important factor in the environment of this swamp. No cutting has occurred and no evidence of burning has been noted. Hunting is fairly common and boys have used the swamp as a swimming hole during high water. Hogs have been seen feeding in the swamp and it is probable that they have modified the vegetation to a slight extent. It is felt, however, that the biotic factors have played a minor role in the vegetation of this interesting swamp forest.

## Summary

1. The virgin black gum swamp analyzed at Pearl River, Louisiana, includes a total of fourteen species of which only *Nyssa biflora* is an important community component.

2. The black gum trees are approximately 200 years old, 83 feet in height, 14.5 inches in diameter at a height of 10 feet, and possess a basal area, at this level, of 338.5 square feet.

3. Unusual features of this swamp are the numerous looping roots and the considerable height (10 ft.) and large diameter (25.7 in.) of the swollen bases.

4. Other interesting features, in common with other primeval swamps, are the abundance of mosses and liverworts on the trunks, the absence of frutescent and herbaceous strata, and the practically barren forest floor.

5. The paucity of species in the understory is attributed to the long hydroperiod, the great amplitude in water level, and the dense shade which obtains in this deep swamp forest.

## REFERENCES

Cain, S. A. and W. T. Penfound. 1938—Aceretum rubri: the red maple swamp forest of Central Long Island. Amer. Midl. Nat. **19**:390-416.

Kurz, Herman and D. Demaree. 1934—Cypress buttresses and knees in relation to water and air. Ecology **15**:36-41.

Penfound, W. T. and E. S. Hathaway. 1938—Plant communities in the marshlands of Southeastern Louisiana. Ecol. Mono. **8**:1-56.

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# On the Viability of Algae Obtained from the Digestive Tract of the Gizzard Shad, Dorosoma cepedianum (Le Sueur)

Gregorio T. Velasquez

CONTENTS



**Foreword**

During his stay in the United States the writer wished to make a study of the ecological relation of phytoplankton to a vegetarian fish because the most prized fresh-water food fish of the Philippines is vegetarian in its food habits and seems to exercise, where it is abundant, a definite influence on the specific composition and numerical relation of the algal flora of the water in which it lives. It seemed desirable, before investigating the ecological relations of the Philippine milkfish to the algae of the ponds in which it lives, to undertake a similar study in the United States.

There had already been a suggestive short study by Tiffany (1927), formerly of Ohio State University, on the algal food identified in the alimentary canal of a single specimen of the gizzard shad, *Dorosoma cepedianum* (Le Sueur). Whether algae sufficiently well preserved to be identifiable were also viable after passage through the alimentary canal of this fish was not known. Apparently efforts to culture algae from the excreta of fish had not been made. It was possible that in overstocked waters fish might actually increase the abundance of the algae (if there were such) that were capable of surviving passage through the alimentary canal of a fish, at the expense of species more easily digested. It was likewise possible that in overstocked ponds the relative abundance of various algae might be changed by the physiological action of materials excreted by the fish or secondarily produced from fish excreta by bacterial action. The relations were, it seemed, entirely unknown.

Environmental factors are extremely difficult to study separately in order

* Papers from the Department of Botany of the University of Michigan, no. 696.

to determine their effect on the ecology of any organism. Especially difficult would it be to unravel the tangled ecological interrelationships of fish and phytoplankton, but it seemed that a good beginning might be made by determining for such a fish as the gizzard shad just what algae are capable of surviving passage through the alimentary canal in a living state. Other relationships might be worked out later.

Through arrangements kindly made by Dr. C. L. Hubbs, of the University Museums, and Professor H. H. Bartlett, of the Department of Botany of the University of Michigan, with the Natural History Survey Division of the state of Illinois, materials were provided for this investigation during the summer and autumn of 1938.

The writer had the pleasure of working with the staff of the Illinois Natural History Survey Division under the direction of Dr. D. H. Thompson. Ten days (July 8-17, 1938) of intensive work devoted to collecting the material were spent at Urbana, during which time the first set of cultures from the intestinal content of gizzard shad were started in the laboratory. The original test tube cultures were brought to the Department of Botany, University of Michigan, five days after inoculation, and transfers were made to larger volumes of culture fluid in Erlenmeyer flasks. After the technique of culturing had been established subsequent lots of fish were shipped in ice from Urbana to Ann Arbor, where the cultures were made.

The writer wishes to express his thanks and appreciation to Dr. D. H. Thompson and staff, especially to Dr. D. F. Hansen, assistant zoologist of the State Natural History Survey Division of Illinois, for various courtesies extended to him during the entire time of the investigation. Mr. G. W. Bennett, the limnologist of the Survey Division, was most generous in giving all possible assistance in the hunt for gizzard shad from the different lakes visited. Laboratory and field facilities were furnished freely and with good will during the writer's brief stay at Urbana.

Throughout the progress of the studies invaluable suggestions of the several members of the writer's doctoral committee at the University of Michigan have been available. Finally, Dr. Francis Drouet of the Field Museum of Natural History at Chicago, Illinois, has most obligingly confirmed identification in the group of his specialization, the Oscillatoriaceae.

### Literature

Many investigators have done important research on the feeding habits of fish. The classical work of Stephen A. Forbes (1878) on the food of Illinois fishes certainly stimulated others to pursue similar investigations. A. S. Pearse (1918) studied 32 fishes in Wisconsin lakes, and other naturalists, including Turner (1921), De Ryke (1922), Clemens (1923), Adamstone (1924), Nurnberger (1928), Cable (1928), and Cassidy (1930), were likewise pioneers. However, not a single one of them classified the food of the fishes as obtained from the digestive tract beyond giving their common or generic names.

L. H. Tiffany in two papers (1921, 1922) made an excellent study of the

algal food of *Dorosoma cepedianum* (gizzard shad), which he observed to be a highly vegetarian fish. He was able to identify 150 species and varieties of algae in the digestive tract. E. Coyle (1930), in a similar study, determined no fewer than 128 species from another fish, *Pimephales promelas* (fathead minnow).

These papers are very elucidating indeed. An excellent taxonomic determination was made of the algae of which at least some of the cells or filaments maintain their distinctive structure sufficiently to provide for microscopic identification after passing a considerable distance through the alimentary canal of the fish. One can wonder why some other investigator has not already attempted to find out whether or not these algae, apparently not affected by the process of digestion, were viable and capable of being cultured. It seems to have remained for the writer to conduct the observations to settle this matter.

For the last half century algae have been grown abundantly for study in various culture media. Cultured algae have been utilized both for taxonomic determination and for physiologic experimentation. G. M. Smith (1916) made use of pure cultures in his studies for a monograph of *Scenedesmus*. B. M. Bristol (1920) obtained 64 species and varieties of algae from cultures of desiccated soils. Many investigators, indeed, including physiologists, handle algae in experimental cultures, subculturing from single cells, as may be necessary, in order to separate individual species from the mixed cultures that generally result from inoculating with natural water, soils, etc. It might, therefore, open an entirely new phase of ecological study if algae could be cultured from the content of the alimentary canal or from the excreta of fish.

It seemed likely that some species might have resistant spores which would escape digestion whereas others would not, and that the increase of undesirable algae in nature might thus be caused in part by selective digestion of the more desirable food species. Or, regardless of the modified cells such as resting spores, some algae might, even in a vegetative state, be resistant to the action of the digestive enzymes of the fish. The gelatinous membranes of some algae might themselves be indigestible and, possibly by adsorption of enzymes, might protect the digestible protoplasm from the action of the digestive fluids.

The overstocking of fish ponds in the Philippines, for instance, is often or generally followed by a great predominance of blue-greens, which give the fish a bad taste. Is this predominance to be attributed entirely to the increase of organic nitrogen in the water from the excretions of the fish, or is it partly or wholly because blue-greens pass through the alimentary canal in a viable state, whereas the greens are usually killed and dissolved by the digestive fluids? These questions seemed to be fundamentally important for the understanding of the ecological balance of fish ponds in which vegetarian fish are an important part of the fauna.

The object of the investigation was, therefore, to make a beginning in studying the possible effect of a fish population, as an agent of natural selection, upon the composition, qualitative and quantitative, of the algal flora.

**Habitat and Habits of the Gizzard Shad**

The gizzard shad, *Dorosoma cepedianum* (Le Sueur), an inhabitant of fresh water, is found in rivers, small streams, ponds, and lakes. It is common in the states of Ohio and Illinois, along the Mississippi valley, in Lakes Erie and Michigan and in brackish water along the Atlantic to the Gulf of Mexico. It is active, darting here and there in the water, and to judge from the microscopic examination of the material in its digestive tract, it is possible that it may sometimes nibble on filamentous algae in addition to straining out plankton on its gills. Its eating activity is probably greatest during summer, since it hibernates in deeper water in winter.

As the fish swims with mouth open the numerous fine gill rakers serve as very efficient strainers and separate even the finest particles present in the water which enters the mouth and passes out through the gill slits. The accumulations of fine particles, usually plankton, are swallowed. Tiffany (1922), because of its unusual process of obtaining food, described the fish as a "living tow net." He was able to compare accurately the algal floras of the ponds and streams of Ohio and Illinois by examining the algal contents of the gut of the fish seined from various localities. In a recent book (1938) he writes: "Among the fishes the gizzard shad is perhaps the greatest collector of fresh water plankton known to-day." The adult fish, about two and a half years old, such as those used in the cultures, has an extraordinary development of the digestive tract, which is longitudinally coiled and twenty-five to twenty-eight inches long. It is thickly beset with finger-like villi at the anterior portion; the thick-walled muscular stomach is so constructed as to simulate the gizzard of most birds. As a food fish, the gizzard shad has been very little esteemed because of its coarse flesh, numerous spines, and not too delicate flavor. However, it would be a mistake to underestimate its immense utility especially when young, for it serves as a very efficient link in the food chain leading from the phytoplankton to almost all game and highly valued market fish produced in American fresh waters. Its inestimable value lies in the fact that it directly transforms, at a single step, microscopic vegetable food into flesh which, only once more reworked by digestion and reassimilation, finally appears in the form of the fish that are more highly esteemed by sportsmen and fishermen.

**Culture Media**

For the cultures set up at Urbana five different media were used. Two of the formulae were obtained from Fred and Waksman's Laboratory Manual of Microbiology (1928), in which they were recommended for the culture of algae. These were Detmer's solution, mainly calcium nitrate made up in tap water, and Bristol's solution, sodium nitrate, also made up in tap water. As a check upon the sufficiency of these media each was diluted with an equal volume of tap water, so as to reduce the concentration of the added nutritive salt and correspondingly to increase the proportion of the numerous other constituents dissolved in the tap water. The fifth culture solution was lake water from the place where the fish were caught; the idea in using it was to retain the same medium in which the algae lived before being eaten by the fish.

All these media were sterilized in the autoclave for 15 minutes at 15 lbs. pressure, in the tubes or the small flasks in which the cultures were made.

Of the five media employed in the first set of cultures Detmer's solution gave the richest growth of algae during the first five and one-half weeks. Hence in making up subsequent cultures only Detmer's formula was used. This solution supplied the algae with the richest nourishment, whereas lake water was the poorest culture medium. (See Figure 1 for comparative growth of the algae in the five media). Figure 2 shows the flasks used in the cultures of the second series (from fish No. 2), in which the effect upon growth of five different media was studied in order to determine which one should be employed in subsequent cultures. Detmer's solution (labeled 1D on the flasks) was selected as the best, since it was conducive to the most luxuriant growth of the algae. Its formula follows:

| | |
|---|---|
| Calcium nitrate, $Ca(NO_3)_2$ | 1.00 gm. |
| Potassium chloride, KCl | 0.25 gm. |
| Magnesium sulphate, $MgSO_4 \cdot 7\ H_2O$ | 0.25 gm. |
| Monopotassium phosphate, $KH_2PO_4$ | 0.25 gm. |
| Tap water | 1000.00 cc. |

Dilute 1 part of the above medium with 2 parts of tap water and add 0.01 per cent of ferric chloride, $FeCl_3 \cdot 6\ H_2O$.

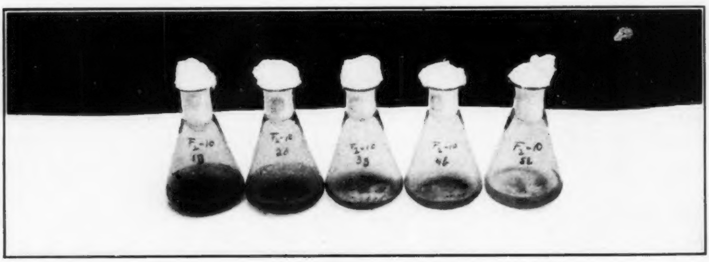


Fig. 1. Samples from each of the five culture media used. Note the abundant growth as indicated by very dark color of the solution; the gradual loss of color in other flasks is due to the smaller number of algae.

Inoculations from material in the anal portion of the alimentary canal showed most abundant growth in Detmer's solution as compared with similar inoculations from the same portion in other culture media. Lake water gave the poorest growth, as can be seen very well from Figure 1.

**Sources of Material; Methods**

The fish caught at Homewood Lake, Decatur, Illinois, in a coarse-meshed seine were killed instantly by cutting the backbone behind the head. They died within two minutes without a flap in the portable icebox which was

taken to the field. It was, of course, desirable to prevent, if possible, any movement of the food in the alimentary canal which might take place after the fish were caught, and especially to kill the fish in such a way that material in the posterior end of the gut would be retained.

Back at the laboratory, a smooth cut on the side of the abdominal region was made and the full coil of the alimentary canal removed to the dissecting dish. The intestinal coil was loosened and spread on a clean white paper, freshly removed from the original package and not unnecessarily exposed. The most anterior portion of the gut and its anal portions were knotted tightly with fine dental floss to stop as much as possible any escape of food. Ten equal divisions of the canal, each about two and one-half inches long, were tied by floss knots, so as to separate the food content of each part from that of the next.

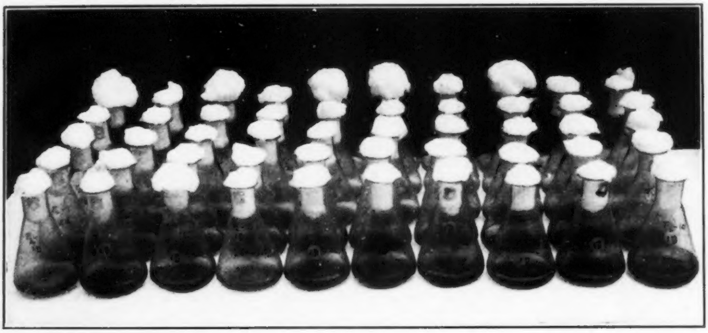


Fig. 2. A set of culture flasks as set up for culturing the intestinal content of fish No. 2, and also for determining the procedure to be used for the subsequent cultures.

Finally, the ten portions were successively cut off at one end, making an open-ended sack of each piece. The food content was pressed gently through the free end into a sterile Petri dish by means of a pair of sterile portable forceps. From here, three wire loop-fulls were inoculated into each of the five sets of test tubes containing the different media. The remainder of the food on the Petri dish was preserved in Transeau's solution to be used later for comparing the identifiable algae in the alimentary canal with those that developed in culture. Transeau's solution, 6 parts of water, 3 parts of ethyl alcohol, and 1 part of commercial formalin, had been found excellent for preserving the cell contents of the algae in samples intended for determinative study.

The original stock cultures in the test tubes were maintained at 4°-10° C. in the refrigerator until taken to Ann Arbor at the end of four or five days. Here the transfers were made by taking only 3 cc. in a graduated pipette from each test tube and inoculating a 125 cc. Erlenmeyer flask containing 30 cc. of culture solution.

The same process was followed with the shads caught at Lake Decatur, except that these fish were obtained by hoop nets. Hoopnetting has a certain disadvantage, in comparison with seinenetting, in that the fish caught are usually left too long in confinement, so that they lose much of the food content of the gut by natural excretion. It is desirable, in such studies as this, to catch fish with a seine. It is certain if this is done that they have been feeding normally up to the time of catching. Fish caught in hoop nets not only remain varying lengths of time without normal feeding but may be already dead when recovered.

The two sets of cultures started at Urbana from gizzard shads caught in different lakes were incubated in separate rooms. One set of flasks, labeled $F_1$-1 to $F_1$-10 ($F_1$ designating fish No. 1 caught at Homewood Lake), were put in a small glass house, in the court of the Department of Botany, that received diffused morning sunlight for about three and one-half hours daily. The other group (see Fig. 2), $F_2$-1 to $F_2$-10 (cultures from fish No. 2, from Lake Decatur), were placed in a room receiving diffused sunlight three to four hours daily beginning at noon. The temperature of the glass house and that of the room differed by only 3° C. from the averages of 26° C. and 23° C. respectively during five and one half weeks of daily observation. The ultimate amount of algal growth in the two places was not observably different, but the flasks in the glass house with slightly higher temperature manifested abundant growth just a week earlier than those in the cooler room. With such a very slight difference in the result it was thought wise to set up duplicates of the flasks, but to place them in a very cold room with diffused light at 10° C. Different algae are affected differently by change of temperature. Since the refrigerator room was very much cooler than the other two rooms, the algae grew slowly. The net result of the experiment with refrigeration was that it used up about twice the length of time that would have been required for abundant growth of the same algae if they had been cultured at the more favorable temperatures of 26° C. and 23° C. mentioned above. Of course, a low temperature has a retarding effect on the rate of growth of most organisms. The species of algae, however, even if not their relative abundance, remained the same as in the other cultures. There was no selective elimination of species either at the lower or the higher temperatures (Table 1). (See pp. 400-401.)

The shad from which the four other sets of cultures were obtained were packed in ice and sent from Urbana to Ann Arbor by express. The sources of the fish and the details of culturing are as follows:

| Fish | Place and Date Caught | Means of Capture | Date of setting up culture |
|---|---|---|---|
| No. 3 | Lake Decatur, August 25 | hoop net | August 27 |
| No. 4 | Weldon Springs Lake, September 8 | hoop net | September 14 |
| No. 5 | Lake Decatur, October 6 | hoop net | October 10 |
| No. 6 | Quiver Lake, October 20 | seine net | October 21 |

Only Detmer's culture solution was used in all these later cultures. A prolonged delay of food in the gut took place before the culture solutions were

TABLE 2.—Summary of Viable Algae Recorded in Cultures Inoculated from Six Different Gizzard Shads

| KINDS OF ALGAE | CULTURES FROM SIX FISH | | | | | |
|---|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 6 |
| MYXOPHYCEAE | | | | | | |
| *Chroococcus minutus* (Kützing) Nageli | x | xx | xx | | | x |
| " *dispersus* var. *minor* G. M. Smith | xx | | | xx | xxx | xx |
| *Microcystis aeruginosa* Kützing | | | | | | x |
| " *flos-aquae* (Wittrock) Kirchner | x | | | | | |
| *Merismopedia punctata* Meyen | | | x | | | x |
| *Oscillatoria prolifica* (Greville) Gomont | xxx | | | | | |
| " *Grunowiana* Gomont | xx | xx | | | | |
| *Phormidium tenue* (Meneghini) Gomont | x | | | | | |
| " *lucidum* (Agardh) Kützing | x | xxx | | | | |
| *Lyngbya aestuarii* (Mertens) Liebmann | xxx | x | | | | |
| *Anabaena catenula* (Kutzing) Bornet + Flahault | | xxx | x | | | |
| *Nostoc spongiaeforme* Agardh | xxx | | | | | |
| HETEROKONTAE | | | | | | |
| *Tribonema cylindricum* Heering | | | | | | x |
| *Bumilleria sicula* Borzi | | x | | | xx | xx |
| BACILLARIEAE | | | | | | |
| *Cyclotella Meneghiniana* Kützing | xx | xx | x | | | x |
| *Diatoma* sp. | | | | | | x |
| *Navicula* sp. indet. No. 1 | x | xx | | | x | x |
| *Navicula* sp. indet. No. 2 | xx | xx | x | | | xx |
| CHLOROPHYCEAE | | | | | | |
| *Sphaerocystis Schroeteri* Chodat | xx | xx | xxx | xx | xx | xx |
| *Microspora floccosa* (Vaucher) Thuret | | | | | | x |
| *Protococcus viridis* Agardh | xxx | x | xx | x | xx | x |
| *Pediastrum tetras* (Ehrenberg) Ralfs | | | | | | x |
| " *integrum* Nägeli | x | | | | | |
| " *simplex* (Meyen) Lemmermann | | | | | | x |
| " *duplex* Meyen | | | xx | x | x | x |
| " " var. *rotundatum* Lucks | x | | xx | | x | |
| " *Boryanum* (Turpin) Meneghini | | x | x | | | x |
| " *biradiatum* Meyen | | | xx | | x | x |
| *Ankistrodesmus falcatus* (Corda) Ralfs | x | xx | | | xx | xx |
| " " var. *tumidus* (W. + G. S. West) G. S. West | | xx | | | | x |
| " *convolutus* Corda | x | x | x | | | xx |
| *Kirchneriella obesa* (W. West) Schmidle | | | | | x | x |
| *Quadrigula lacustris* (Chodat) G. M. Smith | x | | | | | |
| *Tetraëdron trigonum* (Nägeli) Hansgirg | | x | xx | | | |
| *Scenedesmus obliquus* (Turpin) Kützing | x | x | | | x | xx |
| " *dimorphus* (Turpin) Kützing | xx | xx | xx | x | x | xx |
| " *acuminatus* (Lagerheim) Chodat | | x | x | x | x | x |
| " *bijugus* (Turpin) Lagerheim | x | x | x | | | x |
| " *armatus* (Chodat) G. M. Smith | xx | x | xx | xx | x | x |
| " *denticulatus* Lagerheim | x | x | | | | |
| " *longus* Meyen | x | | x | x | | x |
| " *abundans* (Kirchner) Chodat | x | | x | | | |
| " *quadricaudus* (Turpin) de Brebisson | | | | xx | x | x |
| *Crucigenia irregularis* Wille | | | x | | | |
| *Actinastrum gracillimum* G. M. Smith | | x | xx | | | |
| " *Hantzschi* Lagerheim | | x | xx | | | |
| *Closterium moniliferum* (Bory) Ehrenberg | | xx | | | | |
| *Cosmarium* sp. | | | x | | | |
| EUGLENOPHYCEAE | | | | | | |
| *Euglena viridis* Ehrenberg | xxx | xxx | x | | | x |

inoculated. The delays were two days for Nos. 3 and 6, and six and four days, respectively, for Nos. 4 and 5. The distance that the fish had to travel after having been caught in lakes out in the country, plus the railway transportation, account primarily for the loss of time. However, the viable algae recorded in the later cultures compared very favorably in number of species with those of Nos. 1 and 2, as shown in Table 2.

It would naturally be expected that the prolonged delay in culturing the ingested food of the dead fish might result in such excessive action of the digestive fluids that no algae would be left alive. However, the rate of digestive action may be assumed to have been reduced to less than a quarter of the normal rate by packing the fish in ice for shipment. The estimate is based upon an application of the rough rule that a chemical reaction is generally doubled in rate by an increase in temperature of 10° C. The temperature of the water in which the fish were caught was probably about 20° C., and the temperature of shipping about 0° C. The rate of digestion may therefore have been reduced to one-fourth. At any rate, many algae remained viable and the following data (Table 3) show a numerical comparison of viable species and varieties according to the length of protracted incubation of food in the alimentary canal.

TABLE 3.—Comparison of number of species of algae remaining viable in the alimentary canal of the gizzard shad, after one, two, four, and six days.

| Culture | Days before making inoculation | Algal species and varieties |
|---|---|---|
| 1 | one day | 27 |
| 2 | one day | 26 |
| 6 | two days | 30 |
| 3 | two days | 24 |
| 5 | four days | 15 |
| 4 | six days | 9 |

The results indicate that there is almost surely a reduction in number of algal species with increase in length of exposure to the digestive juices. It would take much more experimentation, however, comparing cultures from several fish caught at the same time but retained varying lengths of time after death, in order to get fully significant data. So far as the results go they indicate that if species survive exposure to the digestive juices at all, they are likely to remain viable for two days in the alimentary canal at 0° C., but that after the second day a rapid elimination of species sets in, for only a third as many as could be cultured at the end of six days as experience indicated would presumably have been viable within the first day or two.

## Observations

It was very surprising indeed that the growth of a "bloom" found to be *Oscillatoria prolifica* was immediately observed in cultures of fish No. 1 three days after the solutions were inoculated at Urbana. Simultaneously, *Euglena viridis* in abundance was also discovered, all of the individuals actively swimming. It seemed that of these two species, *O. prolifica* is less adversely affected

by the digestive juices present in the fish because *E. viridis* slowed down to an amoeboid movement. The examination was made when the food was just removed from the digestive tract. This movement is a physiological reaction of this organism to somewhat adverse condition and precedes formation of resting cells which is the best means of protection. Both, however, were found to survive complete passage of the alimentary canal and were dominant over all other algae during the first ten days of the culture. They displayed in the flasks various shades of color from deep grass-green to blue-green. Evidently if grass-green coloration was manifested, *E. viridis* was dominant, whereas blue-green coloration indicated predominance of *O. prolifica*. All other algae, mostly green and blue-green, showed growth not very much later.

In cultures from the second fish, *Euglena viridis* was the dominante organism for approximately a week and a half in the flasks; the rest of the algae appeared later as in the cultures from No. 1.

It had been an idea since the experiments were started to find out which portion or portions of the alimentary canal would give the greatest number of viable algae. It would seem that as digestion proceeded and the food moved posteriorly, there might well be progressive elimination of species. The answer to such a problem might, however, be affected by the amount and quality of food eaten by the fish at different times. The food of the gizzard shad is swallowed as an accumulation obtained by straining water through the gills. It undergoes a controlled peristaltic movement in passing along its way posteriorly. Now, the fish with its habit of constant feeding, may sometimes be in water less rich in plankton, and therefore have less food available than usual, or the food may even change in quality, hence portions of the digestive tract will tend to show at different times various amounts and kinds of algae. Such a phenomenon is shown in Figure 3, where in the series of ten flasks of the second set of cultures, in Detmer's solution, each representing an inoculation from a different part of the digestive tract, the stomachal portion, segment 1, has the least growth. Segments 4 to 6 follow successively in showing small amounts of algae which are evidently less than in the cultures from segments 7 to 10 and 2 to 3 of the alimentary canal. The conclusions is that this particular fish had been inactive or had been in relatively unpopulated water for the period during which algae, if eaten, would just have reached the gizzard region. All the algal food which the fish had eaten had been passed already to segments 2 and 3. The relative emptiness of segments 4 to 6 is explained as indicating that for a certain period of time the fish had been straining from the lake water and swallowing less food than during the time in which the immediately preceding segments 2 and 3 were supplied, or during which the food in segments 7 to 10 had been ingested. Relatively full segments represented periods of rapid straining and swallowing of plankton.

It is very fascinating to follow up in imagination the mechanical passage of food backward in fishes. At whatever moment food is swallowed, peristaltic movement of the alimentary canal begins to move it slowly but continuously, while digestion proceeds, to the anal portion, and then to bring about the excretion of the undigested residue. At the same time, if digestion has a

very slow effect upon certain algae, and faster upon others, in a fish such as the gizzard shad which feeds continuously, many species of algae have chances of passing out as excrement without being killed. The periodic excretion of food residues, whether yet entirely devoid of living algal cells or not, is an inevitable physiological process due to the nature of feeding, as long as the fish is in an active state. Therefore those undigested algae once excreted by the fish will be washed free of inhibiting or harmful substances from the alimentary canal and will start again to grow in nature. The fish may therefore act as a factor in the struggle for existence adverse to some algae (those digested, of which many might be mentioned that are common in waters inhabited by the gizzard shad, but never recovered by culture from the gut content) but favorable to others (those passed alive). If this is true for the gizzard shad, must it not be true for similar vegetarian fish such as the milkfish in the Philippines? And may not the foul condition of some of the over-

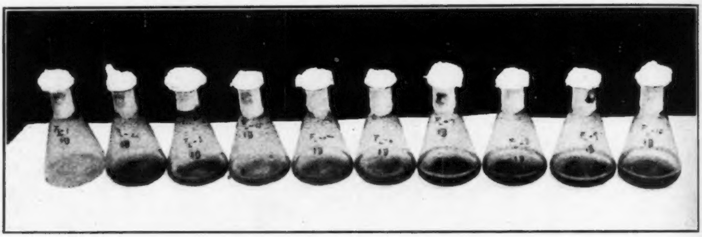


Fig. 3. Comparative study of the abundance of algal growth from the gizzard portion, $F_2$-1, to the anal portion, $F_2$-10.

populated fish ponds represent a condition that favors undesirable algae, those that give rise to disagreeable odors in the water and correspondingly bad flavors in the fish? Furthermore, may not the excessive nitrogenous fertilizing of the water by the excreta of the fish favor still further those types of algae which are undesirable from the standpoint of fish culture? It seems that mere over-population with fish and selective elimination of desirable algae might upset the equilibrium of life in pond waters sufficiently to damage the quality of the fish as human food by increasing the amount of such undesirable algae as oil-bearing blue-greens.

Breder and Crawford (1922) have shown in six minnows of the cyprinoids that silica in the diatoms and cellulose in the cell walls of many algae generally escape solution even throughout a protracted stay in the alimentary canal. However, the great insolubility and chemical inertness of silica would not be expected to be any protection to diatoms if their protoplasts extended through minute pores and slits of the shell, pores too small to be resolved as actual openings by the higher powers of the microscope, but nevertheless, if capable of establishing protoplasmic continuity between the inside and the outside of the shell, also capable of offering free access of the digestive enzymes to the

protoplast within the shell. In accordance with the idea that variously perforated silica armament would prove to offer no protection to the diatoms, these organisms were found to be almost uniformly killed by passage through the alimentary canal. Of the diatoms, *Cyclotella Meneghiniana, Fragilaria, Pinnularia, Gyrosigma, Gomphonema, Diatoma, Eunotia* and at least six species of *Navicula* were identified from the gut contents of fish Nos. 1, 2, 3, and 6, and all of these were probably alive when ingested. Only four species, at best, survived, and it is very interesting that the fish caught in hoop nets and not immediately cultured gave no living diatoms at all. Diatoms, then, are a group marginal in their resistance to digestion, not so quickly destroyed as filamentous greens, and, on the contrary, incapable of withstanding long exposure to digestive juices.

Those algae with cellulose walls might be expected to be preserved from digestive action unless the cells were ruptured during passage through the digestive tract. However, it must be admitted that we know nothing in detail about the chemical composition of the walls which are supposed to be cellulose in the algae. It is by no means impossible that even if the digestive enzymes of fish are unable to act upon cellulose, there may be bacteria or fungi in the alimentary canal of fish, even as in herbivorous animals, which are capable of digesting cellulose and, by dissolving, or at least perforating, the cell walls, exposing the protoplasmic content of the algae to digestion. It is not ordinarily profitable for speculation to run too far in advance of experimentation, but it would be interesting indeed to culture the content of fish intestines upon bacteriological media, with the object of finding out whether any of the bacteria or other fungi isolated would be capable of digesting cellulose. Furthermore, the possibility must not be overlooked that mere mechanical rupture of cell walls might result in exposing the protoplasts of some species to destruction by digestion.

The chemical basis of resistance is at present quite unknown, and it may prove to be nothing so complicated as whether or not the unbroken cell walls of the several algae are or are not dissolved or perforated by fish enzymes or by bacterial enzymes. It may simply be that the disturbance of the respiratory function of the algae in the possibly deoxygenated alimentary canal may cause the death of the more delicate and sensitive algae.

In the contents of the digestive tract of fish Nos. 3 and 6 there were observed several interesting filamentous green algae, namely *Microspora floccosa* and *Ulothrix, Binuclearia,* and *Spirogyra,* almost in too bad a state of breakdown to be identified, and except for the first, named only to the genus. It was noted that only one of them, *Microspora floccosa,* listed in Table 2, was viable. The conclusion is that the filamentous forms of the Chlorophyceae in general were not able to resist the attack of the digestive enzymes. To make an absolute check on the selective elimination of organisms by digestion, it would be necessary to restrict the movement of the fish by confinement, to make plankton samples from the exact locality in which the fish occurred, to make determinations of all the algae and parallel cultures of the samples collected by the plankton net and by the fish and, finally, to culture the in-

testinal debris from fish confined to a habitat of known plankton content for a long enough period so that previous food would have passed through the digestive tract.

Since the culturing itself and the systematic examination of mixed cultures are exacting and time-consuming tasks, I doubt if anyone would undertake so extended a program if he did not have preliminary evidence that the more detailed attack on the problem would be justified. The work which the writer has done and now presents is not the most exhaustive and critical job that could be planned and done, but is quite as extensive as one would be justified in undertaking as a preliminary exploration of the problem. There is always a gap between what might theoretically be desired and what one can actually accomplish in a given time and under other limiting conditions. The examinations of hundreds of slides from the exceedingly mixed cultures in order to perceive the range of variation of each species, to make sure that uncommon species were not confused with others or entirely overlooked, and to make the necessary measurements, was laborious and took much time.

An attempt to examine the algae population of Homewood Lake where fish No. 1 was seined, and which, by the way, was the only examination of plankton the author did at Urbana, revealed the following algae, in three samples which were obtained by centrifuging two-quart samples: *Oscillatoria prolifica* and *Euglena viridis* in abundance, diatoms, with *Navicula* of several species, *Fragilaria, Synedra,* and *Pinnularia* most common, *Scenedesmus* of several species, *Phormidium, Cladophora, Rhizoclonium* and *Oedogonium.* Two of the diatoms from this sample (*Navicula* spp.) were found to be among the several diatoms observed in the food of the fish subsequently examined. In culture, however, only 3 species of diatoms occurred, the third, *Cyclotella Meneghiniana* not having been detected in the plankton or the food residues in the alimentary canal. The propagation of the latter characteristic centric diatom must have come from very few individuals since it was missed in the previous examinations, although it survived and increased in culture. *Cladophora* was rare in the lake (by non-microscopic examination) and rare in the plankton samples also, but it did not occur at all in the cultures. *Cladophora* filaments broken by wave action and suspended in the water would give cell aggregates large enough to be capable of reproducing the alga if it were capable of surviving passage through the fish. *Cladophora* is not only a generally common filamentous green type, but is so usually seen only in vegetative condition that it presumably reproduces for the most part by fragmentation of vegetative plants. Its complete absence from the cultures is the best actual evidence of the elimination of filamentous greens that is yet at hand.

Breder and Crawford have shown that "chitinous parts of insects can be discerned at times in the excrement of these fishes" (i.e., the six species of minnows discussed in their paper).

Chitin is well known to be one of the most indigestible of all the compounds elaborated by living beings. Since fungus chitin has been described, and it is therefore known that such resistant compounds are not confined to

the animal kingdom, it is at least a fair supposition that some of the algae may produce similarly resistant substances, perhaps in a gelatinous colloid condition. Too little is known of the chemistry of the gelatinous vescicles and sheaths surrounding many algae. In spite of the small amount of material they contain, on a dry-weight basis, they may be extremely efficacious, by virtue of their colloidal nature, in bringing about adsorption of enzymes at the very surface, not permitting their diffusion into the cell, and at the same time they may themselves be very resistant to digestion.

There are, indeed, so many possibilities that would need to be taken into consideration in determining why certain living algae escape digestion by the fish, that it would be useless to theorize about them except as a basis for planning further experimentation. As already stated, the writer's object in making the present investigation was to take the first and obvious step of finding out what, if any, algae actually survived passage of the alimentary canal.

There is a possibility that some algae are even normal constituents of the intestinal flora, capable of existing without light as saprophytes. This possibility has not been at all explored in the present investigation, but is suggested because of the fact that living algae are normal living inhabitants of soils into which it is impossible that light penetrates.

A complete list of viable algae obtained in the six cultures from different sources of fish is given in Table 1 (pp. 400-401), in which relative frequency or abundance of species and varieties grown in the cultures for each portion of the alimentary canal, is expressed as "xxx," abundant, "xx," common, and "x," rare. A summary of the foregoing comprehensive list is given in Table 2 (page 383).

It must be realized that rarity in culture need not necessarily be interpreted as indicating ease of digestion of any particular alga by the fish. Rather, it may merely represent rarity in the food ingested. A very rare species in the water, even if it had a high survival value in the alimentary canal of the fish, might nevertheless be rare in the cultures representing survival, simply because the inoculation could not contain many cells of it.

Twelve species of Myxophyceae were cultured out, among which *Chroococcus dispersus* var. *minor, Oscillatoria prolifica, Phormidium lucidum, Lyngbya aestuarii, Anabaena catenula* and *Nostoc spongiaeforme* were those that thrived abundantly. *Chroococcus minutus* and *Oscillatoria Grunowiana* occur quite commonly, but *Microcystis aeruginosa, Microcystis flos-aquae, Merismopedia punctata* and *Phormidium tenue* were rare.

Among thirty species and varieties of the Chlorophyceae, *Sphaerocystis Schroeteri* and *Protococcus viridis* survive digestion and develop in all cultures more or less abundantly, while *Pediastrum duplex, Pediastrum duplex* var. *rotundatum, Pediastrum biradiatum, Ankistrodesmus falcatus, Ankistrodesmus falcatus* var. *tumidus, Ankistrodesmus convolutus, Tetraëdron trigonum,* four species of *Scenedesmus (S. obliquus, S. dimorphus, S. armatus,* and *S. quadricaudus), Actinastrum gracillimum, Actinastrum Hantzschi,* and *Closterium moniliferum* are of common occurrence. Among those that are rather rare are

four species of *Pediastrum (P. tetras, P. integrum, P. simplex,* and *P. Boryanum), Kirchneriella obesa, Quadrigula lacustris,* five species of *Scenedesmus (S. acuminatus, S. bijugus, S. denticulatus, S. longus,* and *S. abundans), Crucigenia irregularis* and a species of *Cosmarium.* Only one green vegetative filament, namely *Microspora floccosa,* was observed. *Euglena viridis* of the Euglenophyceae is either abundant or common, appearing in at least four of six cultures, while *Tribonema cylindricum* and *Bumilleria sicula* of the Heterokontae had been noted several times in two or three different cultures. In the big group of Bacillarieae, only four were viable: *Cyclotella Meneghiniana, Navicula sp.* indet. No. 1 and *Navicula sp.* indet. No. 2 were common in several cultures, whereas *Diatoma sp.* was observed rarely in one culture.

An attempt to study some of the variation in form and measurement of cells which might have resulted from growth in culture led to a comparison of algae cultured in the cold and warm rooms. Some such comparison seemed to be necessary, since otherwise the accuracy of determination of the species identified from cultures would surely be questioned. In specific determination vegetative cells play an important role. Even slight differences in cell measurement or cell form may assign a specimen to an entirely different species. Comparison of camera lucida drawings, traced on the same scale, of ten species and varieties selected to represent the algae of the culture are shown in Plate 7, Figs. 1 to 10. Likewise, their measurements reduce to microns can be read in Table 4.

TABLE 4.—Comparative Measurements of Ten Kinds of Algae Grown in Two Rooms of Different Temperatures

| KINDS OF ALGAE | COOL ROOM 10° C | | | | WARM ROOM 26° C | | | |
|---|---|---|---|---|---|---|---|---|
| | Diameter of Single Cell | | | | Diameter of Single Cell | | | |
| *Cyclotella Meneghiniana* | 11.5 to 13.5 μ | | | | 11.4 to 17.1 μ | | | |
| *Sphaerocystis Schroeteri* | 11.4 to 16.1 μ | | | | 9.1 to 15.5 μ | | | |
| *Pediastrum duplex* | 9.9 to 13.3 μ<br>8-Celled Coenobium - 41.8 μ | | | | 8.6 to 11.0 μ<br>8-celled coenobium - 38.8 μ | | | |
| | Single Cell | | | | Single Cell | | | |
| *Navicula sp. indet.* No 1 | Length - 21.5 μ | | Width - 5.9 μ | | Length - 25.8 μ | | Width - 6.2 μ | |
| *Actinastrum Hantzschi* | Length - 13.2 to 15.3 μ | | Width - 3.0 to 3.5 μ | | Length - 14.5 to 17.5 μ | | Width - 2.5 to 3.8 μ | |
| *Bumilleria sicula* | 〃 - 25.0 to 30.5 μ | | 〃 - 13.7 μ | | 〃 - 28.8 to 35.2 μ | | 〃 - 16.5 μ | |
| *Ankistrodesmus falcatus* var. *tumidus* | 〃 - 42.0 to 53.0 μ | | 〃 - 3.9 to 4.4 μ | | 〃 - 33.0 to 45.0 μ | | 〃 - 3.3 to 4.8 μ | |
| | 4-Celled Coenobium | | Single Cell | | 4-Celled Coenobium | | Single Cell | |
| | Length | Width | Length | Width | Length | Width | Length | Width |
| *Scenedesmus quadricaudus* | 19.2 to 21.0 μ | 12.0 to 12.8 μ | 12.0 to 12.8 μ | 4.2 to 5.0 μ | 16.0 to 25.6 μ | 9.4 to 16.0 μ | 9.4 to 16.0 μ | 4.5 to 6.1 μ |
| 〃 *denticulatus* | 18.0 to 19.5 μ | 12.5 to 13.2 μ | 12.5 to 13.2 μ | 4.2 to 5.4 μ | 15.9 to 17.3 μ | 10.8 to 12.0 μ | 10.8 to 12.0 μ | 4.2 to 5.0 μ |
| | Diameter of: | | Akinete | | Diameter of: | | Akinete | |
| | Trichome | Heterocyst | Length | Width | Trichome | Heterocyst | Length | Width |
| *Anabaena catenula* | 4.5 to 5.2 μ | 6.8 μ | 12.5 to 14.7 μ | 6.7 to 8.0 μ | 4.5 to 5.5 μ | 6.9 μ | 11.5 to 14.7 μ | 6.5 to 7.2 μ |

In certain species some changes in morphological characters of vegetative cells were apparent and in other species the measurements were slightly modified, but not sufficiently to warrant doubts about the systematic position of the materials concerned.

A greater range of diameter seems to appear in *Cyclotella Meneghiniana* grown in the warm room than in the cool room. The specimens cultured in

the warmer room were on the whole larger, and a relatively small proportion of the specimens were small enough to fall within the diameter range characteristic of the cool cultures. However, the known diameter range, 10.0 to 20.0$\mu$, observed in nature by various systematists has not been exceeded in the cultures. The same situation holds true with *Sphaerocystis Schroeteri,* except that more of the larger specimens grew in the cool room than in the warm room. *Pediastrum duplex* reacted in a parallel manner to *S. Schroeteri,* since the specimens grown in the cool room developed greater diameter of single cells. In *Navicula sp.* indet. No. 1, *Actinastrum Hantzschi,* and *Bumilleria sicula* of the warm room, the lengths and widths of single cells always exceeded the corresponding dimensions of the cultures in the cool room. The reverse was true in *Ankistrodesmus falcatus* var. *tumidus* and both *Scenedesmus quadricaudus* and *Scenedesmus denticulatus.* The measurement for *Anabaena catenula* was the same for both the cool and warm rooms. In general, it seems that there has been a tendency to exaggerate grossly the supposed effect of growth in culture solutions and the differences of algae grown in culture from those found in nature. The forms found in culture were normal, and of size within the limits observed in nature.

In the determination of the algae found in identifiable condition in the food residues of the fish, which algae had of course grown in the lake water under wholly natural conditions, the same specific and varietal criteria were used as in the identification of the algae of the cultures. There were no great enough differences to cause confusion. It must be admitted, however, that the cultures contained many species that were not identified in the food residues. If it be supposed that some of these are merely misidentified growth forms of species differently identified if found in the food residues, the writer can only contravert the criticism by reliance upon the belief that the supposed changes appearing under culture conditions would presumably be of the same order of magnitude in one species as in another, and that in a fair proportion of the total number of species identified, those specimens that had grown in lake water were essentially identical with those that had grown in culture. It is fair to suggest that under reasonably controlled conditions the culture of algae might afford data of great value to the systematic phycologist. There seems in the past to have been on the part of some a quite unreasonable, almost superstitious, aversion to attempting to identify cultured algae. It is similar to the feeling that botanists often had about garden plants before the supposed "changes caused by cultivation" were shown to be quite mythical. There was a time when it was believed that experiment had shown many different algae were all growth forms of the same species. Now we are aware that the experiments were defective, and that the cultures were mixed. Confessedly there is much to be done by way of determining the exact quantitative effect of varying habitats and conditions of culture upon the forms and sizes of algae, but it is at least a fair supposition that such scientific study of variation will establish the distinctness of more species than it will reduce to synonymy as mere growth forms or ecological variations. As an example of the interesting and valuable results that may accrue to phycology through

culture studies, one may instance the monograph of *Scenedesmus* by Smith (1916) and the studies in Philippine Volvocaceae by Shaw (1919).

**Brief Descriptions of the Algae**

In the following descriptions the measurements made by the writer from algae grown in culture are not enclosed in parentheses. The measurements enclosed in parentheses are those taken from the particular literature cited below the description. The object in placing the two sets of measurements together for comparison is to indicate that the cultured material does not show wide deviation in size from that found in nature. In other words, as already stated, the measurements of cultured material are quite in accord with expectation, and there is no reason to distrust identifications even when made from cultured specimens. The object in presenting descriptions in addition to the illustrations is to insure, so nearly as possible, the determinability of the writer's material in the event of changes in present concepts of species or varieties. The brief descriptions include no information derived from any other source than the writer's observations of the cultured algae, with the exception of the measurements in parentheses which are borrowed from the sources indicated.

*Chroococcus minutus* (Kützing) Nägeli (Pl. 1, Fig. 3).—Cells spherical or in colonies of 2-4 enclosed by a somewhat wide, spherical, homogeneous, gelatinous sheath; cell contents pale blue-green, granulose; cells 5.3 to 8.0$\mu$ (5.0 to 7.0$\mu$) in diameter, 6.4 to 8.3$\mu$ (5.0 to 10.0$\mu$) in length.

Smith (1920) p. 28, Pl. 1, Fig. 1.

*Chroococcus dispersus* var. *minor* G. M. Smith (Pl. 1, Fig. 4).—Cells spherical, forming irregular colonies; individual cells some distance from one another within the colony; cell sheaths transparent and confluent with colonial sheath; cell contents homogeneous, pale blue-green; cells 1.4 to 4.0$\mu$ (1.8 to 2.5$\mu$) in diameter.

Smith (1920) p. 28, Pl. 1, Fig. 3.

There seems to be a wide variation of cell diameter among different colonies, so the cells of greater diameter (3 to 4$\mu$) may represent an admixture of *C. dispersus* (v. Keissler) Lemmermann with var. *minor*. This supposition was not tested by single-cell cultures.

*Microcystis aeruginosa* Kützing (Pl. 1, Fig. 2).—Colony saccate and somewhat clathrate; gelatinous envelope of colony homogeneous, hyaline and indistinct; cells spherical and evenly distributed throughout the colony, fairly close together; cell contents homogeneous, pale, with numerous pseudo-vacuoles and reddish; cells 3.0 to 3.6$\mu$ (3.0 to 4.0$\mu$) in diameter.

Smith (1920) p. 39, Pl. 5, Fig. 1.

Very small colonies were found in culture.

*Microcystis flos-aquae* (Wittrock) Kirchner (Pl. 1, Fig. 1).—Colonies spherical; cells somewhat crowded, evenly distributed within a very delicate, hyaline, homogeneous, gelatinous envelope; margin of colony not distinct; cell contents not homogeneous, very pale blue-green; pseudo-vacuoles present; cells 5.8 to 8.9$\mu$ (3.5 to 6.5$\mu$) in diameter.

Smith (1920) p. 39, Pl. 5, Fig. 5.

The specimen differs from *Microcystis aeruginosa* by the character of its colonial envelope and the larger size of the cells.

*Merismopedia punctata* Meyen (Pl. 1, Fig. 5).—Colonies small, with cells some distance from one another but regularly arranged in rectilinear series; cells spherical to broadly ovate; cell contents homogeneous, pale blue-green; cells 2.9 to 3.5$\mu$ (2.5 to 3.5$\mu$) in diameter.

Smith (1920) p. 33, Pl. 2, Fig. 3.

*Oscillatoria prolifica* (Greville) Gomont (Pl. 2, Fig. 1).—Plant mass greatly expanded, forming "bloom," pale blue-green; trichomes straight throughout, elongate, somewhat flexible, not constricted at joints, tapering slightly at apex, obtuse, capitate; cells subquadrate, or a little longer than wide; cell contents refringent, coarsely granular; trichomes 3.2 to 4.5$\mu$ (2.2 to 5.0$\mu$) in diameter; cells 3.8 to 5.0$\mu$ (4.0 to 6.0$\mu$) in length.

Gomont (1892) p. 205, Pl. 6, Fig. 8. Tilden (1910) pp. 61 to 62, Plate IV, Fig. 1.

The formation of "bloom" of this alga was observed three days after the culture was set up and lasted several weeks thereafter.

*Oscillatoria Grunowiana* Gomont (Pl. 2, Fig. 2).—Filaments pale blue-green; trichomes loose, irregularly arranged, somewhat twisted or straight, fragile, slightly constricted at joints; apex of trichome straight, apical cell rotund; calyptra none; cells 4.8 to 6.1$\mu$ (3.7 to 5.6$\mu$) in width, 2.5 to 3.2$\mu$ (1.4 to 4.0$\mu$) in length; transverse wall lined with fine granules; cell contents pale blue-green.

Gomont (1892) p. 235. Geitler (1925) p. 367.

*Phormidium tenue* (Meneghini) Gomont (Pl. 2, Fig. 3).—Filaments pale blue-green, furnished with a very thin sheath, membranaceous; trichomes elongate, somewhat straight, slightly constricted at joints; cells 1.7 to 2.3$\mu$ (1.0 to 2.0$\mu$) in width, 3.2 to 5.0$\mu$ (2.5 to 5.0$\mu$) in length; apex of trichome not capitate, very slightly tapering; apical cell somewhat conical; transverse wall obscure; cell contents homogeneous, pale blue-green.

Gomont (1892) p. 169, Pl. 4, Figs. 23-25.

*Phormidium lucidum* Kützing (Pl. 2, Fig. 4).—Plant mass firm, strongly grass-green; filaments moderately flexuous, subparallel, sheaths evident in most trichomes, mucous, diffluent; trichomes slightly constricted at joints;

apices erect, apical cell rotund above; calyptra usually present; cross-walls lined with two rows of granules; trichomes 7.2 to 8.0$\mu$ (7.0 to 8.0$\mu$) in diameter, cells 2.1 to 2.4$\mu$ (2.0 to 2.5$\mu$) in length.

Gomont (1892) pp. 179 and 180, Pl. 5, Figs. 11 and 12.

*Lyngbya aestuarii* (Mertens) Liebmann (Pl. 2, Fig. 5).—Plant mass deep blue-green; filaments long, flexible and loosely entangled; sheaths thin, smooth, later becoming thick, roughened on the surface with age, lamellose; trichomes not constricted at joints; apex of trichome truncate, apical cell showing a somewhat thickened outer membrane; cell contents finely granular, deep blue-green; trichomes 11.2 to 13.4$\mu$ (8.0 to 24.0$\mu$) in diameter; cells 2.4 to 3.2$\mu$ (2.7 to 5.6$\mu$) in length.

Gomont (1892) pp. 127-131, Pl. 3, Figs. 1 and 2. Tilden (1910) pp. 120-122, Pl. V, Figs. 40 and 41. Hormogonia present in all trichomes. The filaments formed floccose fascicles creeping on the walls of flasks above the surface of the nutrient solution.

*Anabaena catenula* (Kützing) Bornet & Flahault (Pl. 2, Fig. 6).—Plant mass gelatinous, floating, blue-green; sheaths not distinct; trichomes flexuous; apical cell rotund; cells barrel-shaped, a little shorter than the diameter, heterocysts slightly oblong; akinetes cylindrical with round truncate apices, usually contiguous to the heterocysts, in catenate series; wall of akinete smooth, contents granular; trichome 4.5 to 5.2$\mu$ (5.0 to 8.0$\mu$) in diameter; heterocysts 6.7 to 8.0$\mu$ (6.0 to 9.0$\mu$) in diameter, 8.2 to 8.6$\mu$ (9.0 to 13.0$\mu$) in length; akinetes 6.7 to 8.0$\mu$ (7.0 to 10.0$\mu$) in diameter, 12.5 to 14.7$\mu$ (16.0 to 30.0$\mu$) in length.

Tilden (1910) pp. 191 and 192, Pl. IX, Fig. 17. Geitler (1925) pp. 318 and 319, Fig. 370. The specimens observed in culture were probably young, hence, the akinetes may still have been in the process of growth.

*Nostoc spongiaeforme* Agardh (Pl. 2, Fig. 7).—Plant mass expanded, pale blue-green; filaments flexuous, loosely entangled, sheaths indistinct; cells cylindrical, varying lengths; heterocysts somewhat oblong; akinetes separated in catenate series (not described as catenate in references), walls smooth; cell contents granular; trichomes 3.2 to 3.8$\mu$ (about 4$\mu$) in diameter; cells 4.8 to 8.3$\mu$ (up to 7$\mu$) in length; heterocysts 4.8 to 5.1$\mu$ (7.0 to 8.0$\mu$) in diameter, 5.8 to 7.5$\mu$ in length; akinetes 4.8 to 5.6$\mu$ (6.0 to 7.0$\mu$) in diameter, 7.5 to 12.0$\mu$ (10.0 to 12.0$\mu$) in length.

Tilden (1910) p. 168, Pl. VII, Figs. 4 and 5. Geitler (1925) p. 298.

*Tribonema cylindricum* Heering (Pl. 6, Fig. 8).—Filaments similar in width throughout, 12.5 to 14.1$\mu$ (13.0 to 15.0$\mu$) in diameter; cells 20.8 to 40.0$\mu$ in length, or about three (3-8) times longer than width; cell wall 1.3$\mu$ (1.0 to 1.5$\mu$) in thickness.

Pascher, Schiller and Migula (1925) p. 101.

*Bumilleria sicula* Borzi (Pl. 6, Fig. 7).—Cells with several chromatophores; filaments 16.0 to 20.0$\mu$ (15.0 to 20.0$\mu$) in width; cells 28.8 to 35.2$\mu$ in length.

Pascher, Schiller and Migula (1925) pp. 110 and 111, Fig. 89A.

The vegetative cells observed in culture store a large amount of oil droplets.

*Cyclotella Meneghiniana* Kützing (Pl. 6, Fig. 3).—Frustule in girdle view somewhat rectangular, slightly undulate, valve view 11.4 to 17.1$\mu$ (10.0 to 20.0$\mu$) in diameter; with punctulations.

Boyer (1916) p. 19, Pl. 2, Fig. 8.

*Diatoma sp.* (Pl. 6, Fig. 6).—Frustules quadrate, adnate in filaments, valve linear; chromatophores large granules without definite arrangement; very thin walls, somewhat separating, distinctly punctate.

Boyer (1916) p. 41, Pl. 40, Fig. 11 for habit and chromatophores.

*Navicula* sp. indet. No. 1 (Pl. 6, Fig. 4).—Valve elliptic, ends rounded, subcapitate; axial area distinct; 2 chromatophores; valve 6.2$\mu$ in width, 23.8$\mu$ in length.

*Navicula* sp. indet. No. 2 (Pl. 6, Fig. 5).—More slender than the preceding; valve elliptic with narrow rounded ends; axial area distinct; chromatophores 2; valve 5.4$\mu$ in width, 26.2$\mu$ in length.

Boyer (1916) pp. 89 and 90.

This diatom is usually found in small or large aggregates, whereas *Navicula* sp. indet. No. 1 is always solitary.

*Sphaerocystis Schroeteri* Chodat (Pl. 5, Fig. 1).—Colonies spherical, cells seen in groups of 2, 4, 8, or 16, disposed towards the periphery of a hyaline, homogeneous, gelatinous envelope; cells spherical; chloroplast filling the entire cell with pyrenoid; cells 9.1 to 13.3$\mu$ (6.0 to 22.0$\mu$) in diameter; colonies 30.0 to 97.5$\mu$ (50.0 to 500.0$\mu$) in diameter.

Smith (1920) p. 101, Pl. 19, Figs. 3 and 4.

This alga is either common or abundant in all cultures.

*Microspora floccosa* (Vaucher) Thuret (Pl. 5, Fig. 12).—Cells usually cylindrical, at times quadrate, 14.6 to 18.4$\mu$ (14.0 to 17.0$\mu$) in width; cell wall thin; chromatophores blue-green, oftentimes perforate or reticulate; cells 18.4 to 25.6$\mu$ in length, or 1 to 1½ (1 to 2½) longer than wide.

Heering (1914) p. 152, Figs. 214 and 215.

*Protococcus viridis* Agardh (Pl. 5, Fig. 2).—Cells sometimes solitary, 3.8 to 9.9$\mu$ in diameter, spherical, with relatively thick wall, usually dividing into 2 and 4 comprising a colony; chromatophores lobed at margin, nucleus central.

Lemmermann, Brunnthaler and Pascher (1915) pp. 224 to 226, Figs. 31 and 32.

According to the literature, the greater number of these cells are 8 to 14$\mu$ in diameter; frequently less or more.

*Pediastrum tetras* (Ehrenberg) Ralfs (Pl. 3, Fig. 7).—Coenobium of 8 (4-16) cells, closed, middle cell polygonal with narrow incision; marginal cells appearing as if grown together, two-lobed; incision small, running to the middle of the cell; marginal cell 8.0$\mu$ (8.0 to 27.0$\mu$) in diameter.

Lemmermann, Brunnthaler and Pascher (1915) p. 103, Figs. 64a, b, and c.

The species is very rare: only four 8-celled coenobia were observed in culture.

*Pediastrum integrum* Nägeli (Pl. 3, Fig. 4).—Coenobium of 8 or 16 cells; 8-celled coenobium 66.0$\mu$ in diameter; interior cells polygonal; marginal cells 4- to 6- (5- to 6-) cornered, 16.5 to 24.0$\mu$ (20 to 28$\mu$) in diameter, always with 2 shortened hyaline blunt horns, both mammilliform.

Lemmermann, Brunnthaler and Pascher (1915) pp. 91 and 92, Fig. 51a. Smith (1920) p. 168, Pl. 45, Fig. 7.

The material is probably referable to form *glabra* Raciborski, its membrane being smooth.

*Pediastrum simplex* (Meyen) Lemmermann (Pl. 3, Fig. 1).—Coenobium 16-celled, not opened; interior cells polygonal, marginal cells more or less grown together; inner walls of marginal cells fit with those of interior cells, outer walls producing a single tapering hyaline setum.

Lemmermann, Brunnthaler and Pascher (1915) pp. 93 and 94, Fig. 55a. Smith (1920) p. 167.

Possibly referable to var. *granulatum* Lemmermann because of the fine punctulations on the cell wall.

*Pediastrum duplex* Meyen (Pl. 3, Fig. 2).—Coenobium of 16 cells, with small lens-shaped perforations between the cells; interior cells more or less rectangular, not in contact with one another at the central portion of the side walls; inner half of marginal cells similar to interior cells, outer half prolonged into two short truncate processes; cell wall smooth; cells 12.0 to 17.6$\mu$ (11.0 to 21.0$\mu$) in diameter.

Smith (1920) p. 171, Pl. 46, Figs. 14 to 16.

*Pediastrum duplex* var. *rotundatum* Lucks (Pl. 3, Fig. 3).—The two short truncate processes of marginal cells convex and capitate instead of parallel.

Smith (1920) p. 172, Pl. 46, Fig. 17.

*Pediastrum Boryanum* (Turpin) Meneghini (Pl. 3, Fig. 5).—Coenobium circular, of 16 cells, compactly arranged in concentric rings; interior cells five—

to six-sided, with straight sides; inner half of marginal cells similar to interior cells; outer half produced into two short obtuse processes ending in short spines; slightly emarginate between processes; wall granulated; cells 9.0 to 13.5μ (7.5 to 30.0μ) in diameter, 16-celled coenobia 51.0 to 57.0μ (40.0 to 100.0μ) in diameter.

Smith (1920) pp. 169 and 170, Pl. 46, Fig. 3.

*Pediastrum biradiatum* Meyen (Pl. 3, Fig. 6).—Coenobia of 16 cells, with medium-sized openings between cells; marginal cells in contact with one another at base only, with two long projections that are dilated and incised at apex; interior cells as also those of the margin, in contact with other cells at base or end of projection only; cell wall smooth; cells 9.3 to 12.0μ (10.0 to 22.0μ) in width, 10.5 to 15.0μ (15.0 to 30.0μ) in length; 16-celled coenobia 48.0 to 57.0μ in diameter.

Smith (1920) p. 173, Pl. 48, Figs. 5 to 8.

The specimens were supposedly young as the measurements were at the lower limit of the range of variation.

*Ankistrodesmus falcatus* (Corda) Ralfs (Pl. 5, Fig. 3).—Cells acicular, tapering very gradually to both apices; length to about 14 to 22 (12 to 24) times the diameter; mostly solitary, at times in loosely associated fascicles; chloroplast single; cells 1.5 to 2.0μ (1.5 to 3.5μ) in diameter, 21.0 to 33.0μ (20.0 to 80.0μ) in length.

Smith (1920) p. 134, Pl. 32, Fig. 1.

*Ankistrodesmus falcatus* var. *tumidus* (W. and G. S. West) G. S. West (Pl. 5, Fig. 4).—Either solitary or in small aggregates, straight, inflated at middle and with acute apices; chloroplast single; cells 3.3 to 4.8μ (4.5 to 6.5μ) in width, 33.0 to 45.0μ (61.0 to 73.0μ) in length.

Smith (1920) p. 135, Pl. 32, Fig. 2.

*Ankistrodesmus convolutus* (Corda) (Pl. 5, Fig. 5).—Cells acicular, tapering gradually to acute apices, twisted to loose S-shape, stouter than *Ankistrodesmus falcatus;* chloroplast single, completely filling the cell; cells 1.8 to 2.2μ in diameter, 18.7 to 22.0μ in length.

Smith (1926) p. 182, Pl. 13, Figs. 7 to 9.

*Kirchneriella obesa* (W. West) Schmidle (Pl. 5, Fig. 8).—Cells always solitary, somewhat circular, markedly convex outside, opposite ends brought to within 0.9 to 2.0μ (1.5 to 2.0μ) from each other; cells 2.3 to 2.7μ (2.0 to 4.2μ) in width, 6.0 to 7.5μ (6.0 to 9.0μ) in length; chloroplast single, filling the entire cell.

Lemmermann, Brunnthaler and Pascher (1915) p. 181, Fig. 267.

*Quadrigula lacustris* (Chodat) G. M. Smith (Pl. 5, Fig. 9).—Cells spindle-shaped, slightly curved, with pointed ends, in groups of four with

their long axes parallel to the long axis of the fusiform, gelatinous, colonial envelope; chloroplast single, laminate; cells 2.7 to 3.3μ (3.0 to 5.0μ) in width, 15.0 to 21.0μ (20.0 to 25.0μ) in length.

Smith (1920) p. 139, Figs. 4 to 6.

*Tetraëdron trigonum* (Nägeli) Hansgirg (Pl. 5, Fig. 10).—Cells solitary, triangular, flat, 3 to 4 (3 to 4) corners, rounded, 17.6 to 25.3μ (6.0 to 40.0μ) in diameter, straight or slightly convex sides (instead of concave as described in literature); spines short, straight.

Lemmermann, Brunnthaler and Pascher (1915) p. 149, Fig. 163.

*Scenedesmus obliquus* (Turpin) Kützing (Pl. 4, Fig. 1).—Coenobia generally 4 cells arranged in a single linear or sublinear series; cells fusiform with acute apices; interior cells with straight lines, outer face of terminal cells straight or slightly concave; cell wall smooth, no terminal spine; cells 3.2 to 5.7μ (3.0 to 9.0μ) in width, 9.8 to 17.3μ (10.0 to 21.0μ) in length; 4-celled coenobia 9.8 to 21.0μ (10.0 to 21.0μ) in width, 14.7 to 19.5μ (12.5 to 24.0μ) in length.

Smith (1920) p. 151, Pl. 37, Figs. 12 to 14.

*Scenedesmus dimorphus* (Turpin) Kützing (Pl. 4, Fig. 2).—Coenobia of 4-8 cells arranged in a linear or alternating series; cells fusiform with apices attenuated to delicate points; interior cells erect, outer lunate; cell wall smooth, no spines; cells 4.0 to 5.0μ (2.0 to 5.0μ) in width, 21.0 to 23.3μ (18.0 to 23.0μ) in length; 4-celled coenobia 21.0 to 24.0μ (18.0 to 23.0μ) in width, 22.0 to 24.0μ (12.0 to 25.0μ) in length.

Smith (1920) p. 151, Pl. 37, Figs. 15 to 17.

*Scenedesmus acuminatus* (Lagerheim) Chodat (Pl. 4, Fig. 3).—Coenobia of 4 cells, lunate or fusiform, with the ends gradually tapering to fine points; cell wall smooth, without spines; cells 2.9 to 3.3μ (3.0 to 7.0μ) in width, 21.0 to 23.5μ in length.

Smith (1920) p. 152, Pl. 38, Figs. 1 to 4.

*Scenedesmus bijugus* (Turpin) Lagerheim (Pl. 4, Fig. 4).—Coenobia flat, of 4 cells, sometimes 8 in a single linear series; cells ovoid, with broadly rounded ends; cell wall smooth, no spines; cells 5.2 to 6.2μ (4.0 to 7.0μ) in width, 7.8 to 9.1μ (7.0 to 18.0μ) in length; 4-celled coenobia 7.8 to 9.1μ (7.0 to 18.0μ) in width, 22.8 to 23.7μ (16.0 to 25.0μ) in length.

Smith (1920) p. 152, Pl. 37, Figs. 18 to 20.

*Scenedesmus armatus* (Chodat) G. M. Smith (Pl. 4, Fig. 5).—Coenobia of 2-4 cells arranged in a linear series; cells oblong-ellipsoid with rounded apices; terminal cells with a single spine at each pole; interior cells with a longitudinal ridge that extends only a short distance to the median portion of the cells; cells 4.3 to 5.2μ (4.0 to 7.0μ) in width, 14.3 to 15.6μ (7.0 to

16.0$\mu$) in length; 4-celled coenobia 14.3 to 15.6$\mu$ (7.0 to 16.0$\mu$) in width, 18.2 to 20.2$\mu$ (16.0 to 25.0$\mu$) in length; spines 7.2 to 9.1$\mu$ (5.0 to 7.0$\mu$) in length.

Smith (1920) p. 154, Pl. 39, Figs. 7 to 10.

*Scenedesmus denticulatus* Lagerheim (Pl. 4, Fig. 6).—Coenobia flat, 4-celled; cells ovoid, arranged in a linear series; poles of cells with 2 short spines; cells 4.2 to 5.0$\mu$ (5.0 to 11.0$\mu$) in width, 10.8 to 12.0$\mu$ (7.0 to 15.0$\mu$) in length; 4-celled coenobia 10.8 to 12.0$\mu$ (7.0 to 15.0$\mu$) in width, 15.9 to 17.3 (15.0 to 22.0$\mu$) in length.

Smith (1920) p. 155, Pl. 39, Figs. 17 to 19.

*Scenedesmus longus* Meyen (Pl. 4, Fig. 7).—Coenobia flat, with the 4 cells arranged in a single series; cells oblong-cylindrical with rounded poles; cell wall smooth except at poles, each with one spine; cells 4.2 to 4.5$\mu$ (4.0 to 5.0$\mu$) in width, 11.3 to 11.7$\mu$ (8.0 to 11.0$\mu$) in length; 4-celled coenobia 11.3 to 11.7$\mu$ (8.0 to 11.0$\mu$) in width, 15.8 to 16.5$\mu$ (16.0 to 20.0$\mu$) in length.

Smith (1920) p. 156, Pl. 39, Figs. 20 to 22.

*Scenedesmus abundans* (Kirchner) Chodat (Pl. 4, Fig. 8).—Coenobia flat, 4-celled; cells oblong; terminal cells with two spines at poles and two more spines on each of outer faces between poles; interior cells with 1 or 2 spines at each pole; cells 2.7 to 3.3$\mu$ (4.0 to 7.0$\mu$) in width, 8.8 to 9.3$\mu$ (7.0 to 12.0$\mu$) in length; 4-celled coenobia 8.7 to 9.3$\mu$ (7.0 to 12.0$\mu$) in width, 11.4 to 12.0$\mu$ (15.0 to 30.0$\mu$) in length.

Smith (1920) p. 157, Pl. 39, Figs. 23 to 25.

*Scenedesmus quadricaudus* (Turpin) de Brebisson (Pl. 4, Fig. 9).—Coenobia flat, of 2-4 cells in a simple linear series; cells cylindrical, with rounded poles; poles of terminal cells with a single, stout, long, slightly curved spine; poles of interior cells smooth; cells 4.5 to 6.1$\mu$ (3.5 to 6.0$\mu$) in width, 9.4 to 16.0$\mu$ (11.0 to 16.0$\mu$) in length; 4-celled coenobia 9.4 to 16.0$\mu$ (11.0 to 16.0$\mu$) in width, 16.0 to 25.6$\mu$ (12.0 to 23.0$\mu$) in length; spines 10.4 to 12.8$\mu$ (10.0 to 12.0$\mu$) in length.

Smith (1920) p. 158, Pl. 40, Figs. 9 to 11.

*Crucigenia irregularis* Wille (Pl. 5, Fig. 11).—Coenobia four-celled, with cells in contact at sides and poles; at other times without any definite arrangement; 4 coenobia usually combined into a compound coenobium; cells generally ovoid, with 1 to 2 parietal chloroplasts; cells 4.7 to 5.2$\mu$ (4.0 to 9.0$\mu$) in width, 6.8 to 7.8$\mu$ (6.0 to 14.0$\mu$) in length; 4-celled coenobia 9.1 to 10.4$\mu$ (8.0 to 14.0$\mu$) in width, 14.3 to 16.3$\mu$ (15.0 to 30.0$\mu$) in length.

Smith (1920) p. 145, Pl. 36, Figs. 4 and 5.

*Actinastrum gracillimum* G. M. Smith (Pl. 5, Fig. 6).—Coenobia of four

TABLE 1. — Complete Account of the Algae Viable in Cultures Inoculated from each of the

| Kinds of Algae | No. 1 (Homewood Lake) | | | | | | | | | | No. 2 (Lake Decatur) | | | | | | | | | | No. 3. (Lake Decatur) | | | | | | | | | | No |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 |
| MYXOPHYCEAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Chroococcus minutus | | | | | | | x | | x | | | | | | | x | | xx | | xx | | | xx | xx | | | | | | | |
| " dispersus var. minor | | | | | | | xx | x | xx | | | | | | | | | | | | | | | | | | | | | | |
| Microcystis aeruginosa | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| " flos-aquae | | | | | x | x | | | | | | | | | | | | | | | | | | | | | | | | | |
| Merismopedia punctata | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| Oscillatoria prolifica | | x | xx | xx | x | xxx | xx | xx | xx | x | | | | | | | | | | | | | | | | | | | | | |
| " Grunowiana | xx | | | x | x | x | x | | x | | x | x | | xx | xx | xx | x | xx | xx | | | | | | | | | | | | |
| Phormidium tenue | | | | | | x | x | | x | x | | | | | | | | | | | | | | | | | | | | | |
| " lucidum | | | | | | | | x | | x | | | | | | xxx | | | | | | | | | | | | | | | |
| Lyngbya aestuarii | | | | | | | xx | xxx | | x | | | | x | | | | | x | | | | | | | | | | | | |
| Anabaena catenula | | | | | | | | | | | | | | | x | | | xxx | | | | | x | | | | | | | | |
| Nostoc spongiaeforme | x | x | | | | | | | xxx | | | | | | | | | | | | | | | | | | | | | | |
| HETEROKONTAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tribonema cylindricum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bumilleria sicula | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | |
| BACILLARIEAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cyclotella Meneghiniana | | xx | x | | x | | x | x | | | | xx | x | xx | x | | | | | x | x | x | x | | | | | | x | | |
| Diatoma sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Navicula sp. indet. No 1 | x | | | | x | | | | | | | | xx | x | xx | | | x | | | | | | | | | | | | | |
| Navicula sp. indet No 2 | x | x | xx | xx | xx | | | x | | | | | | | | | xxx | | | x | | | x | x | | | | | | | |
| CHLOROPHYCEAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sphaerocystis Schroeteri | x | x | x | x | xx | | x | | xx | | x | x | xx | x | | x | | x | | | x | x | x | x | xxx | xxx | x | x | x | x | xx |
| Microspora floccosa | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Protococcus viridis | x | | x | | xx | | xxx | | xx | x | | x | x | | | x | | x | | | | | x | | xx | x | | x | | | |
| Pediastrum tetras | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| " integrum | | | | x | | | | | | x | | | | | | | | | | | | | | | | | | | | | |
| " simplex | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| " duplex | | | | | | | | | | | | | | | | | | | | | | xx | | x | x | | x | x | | | |
| " " var rotundatum | x | | x | x | | | | | | x | | | | | | | | | | | x | x | | | | | | | xx | x | |
| " Boryanum | | | | | | | | | | | | x | | | | | | x | | | | x | | | | x | | x | | | |
| " biradiatum | | | | | | | | | | | | | | | | | | | | | | xx | x | | | | | | | | |
| Ankistrodesmus falcatus | x | | | | | | | | | | | | xx | x | | x | | | | | | | | | | | | | | | |
| " " var. tumidus | | | | | | | | | | | | xx | x | x | | x | | | | x | | | | | | | | | | | |
| " convolutus | x | x | | | x | | | | | | | x | | | | | | x | | | | x | | | x | | | | | | |
| Kirchneriella obesa | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quadrigula lacustris | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | |
| Tetraedron trigonum | | | | | | | | | | | | | x | | | x | | | | | xx | | x | x | xx | | xx | x | x | x | |
| Scenedesmus obliquus | x | | x | x | | | | | | x | | | x | | | | x | | | x | | | | | | | | | | | |
| " dimorphus | x | xx | x | xx | xx | x | x | | x | x | x | x | x | x | xx | x | x | x | | | x | x | xx | x | x | xx | x | | x | x | x |
| " acuminatus | | | | | | | | | | | | | | | x | | | | | | x | | | | | | | | | | |
| " bijugus | | | | | | | | | x | | | | | | | | | x | | | | | x | | x | | | | | | |
| " armatus | xx | x | x | xx | x | x | x | x | x | x | | x | | | | x | x | x | x | | x | x | x | xx | x | xx | x | xx | xx | x | x |
| " denticulatus | x | | | x | | | | | | | | | | | | | | x | | | | | | | | | | | | | |
| " longus | x | | x | | | | | | | | | | | | | | | | | | | | | x | | | | | | | |
| " abundans | | x | | | | | | | | x | | | | | | | | | | | x | | | x | | x | xx | | | | |
| " quadricauda | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crucigenia irregularis | | | | | | | | | | | | | | | | | | | | | | x | x | | | x | | | | | |
| Actinastrum gracillimum | | | | | | | | | | | | | | | | | x | x | | | | x | xx | | | | xx | x | | | |
| " Hantzschi | | | | | | | | | | | | x | | | | x | x | x | | | x | xx | xx | x | x | x | xx | x | xx | xx | |
| Closterium moniliferum | | | | | | | | | | | | | | | | | | xx | | | | | | | | | | | | | |
| Cosmarium sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | |
| EUGLENOPHYCEAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Euglena viridis | | x | x | xxx | xx | xx | xx | xx | xx | | | | x | xxx | xx | x | xx | x | x | | x | x | | | | x | | | | | |

oculated from each of the Ten Portions of the Alimentary Canal of Six Different Gizzard Shads

cells radiating from a common center; cells elongate-cylindrical, tapering slowly to a truncate end, 8 to 9 (7 to 10) times as long as broad; chloroplast single, covering the whole cell; cells 1.8 to 2.3$\mu$ (1.8 to 3.0$\mu$) in width, 17.3 to 19.5$\mu$ (14.0 to 21.0$\mu$) in length.

Smith (1920) p. 164, Pl. 43, Figs. 3 to 5.

*Actinastrum Hantzschi* Lagerheim (Pl. 5, Fig. 7).—Coenobia consisting of 4-8 cells radiating from a common center; cells cylindrical, 4 to 7 (3 to 6) times as long as broad, with truncate poles; middle part of cells about twice the diameter of the poles; chloroplast single, parietal; cells 2.3 to 3.9$\mu$ (3.0 to 6.0$\mu$) in width 14.3 to 17.4$\mu$ (10.0 to 26.0$\mu$) in length.

Smith (1920) p. 164, Pl. 43, Figs. 6 and 7.

*Closterium moniliferum* (Bory) Ehrenberg (Pl. 6, Fig. 1).—Cells large, length about 6 (6 to 8) times the width, curvature of outer wall conspicuous, inner wall not as conspicuously curved; apices bluntly rounded; cell wall thin, smooth and continuous without a median girdle; chloroplasts with 5 longitudinal ridges and an axial row of pyrenoids; terminal vacuoles conspicuous; cells 50.2 to 53.6$\mu$ (46.0 to 50.0$\mu$) in width; opposite apices in every cell 289.6 to 296.4$\mu$ (244.0 to 252.0$\mu$) apart.

Smith (1924) pp. 8 to 10, Pl. 52, Fig. 10.

Nucleus and pyrenoids obscured by the thickness of chloroplast; size slightly larger than allowed for in reference.

*Cosmarium* sp. (Pl. 6, Fig. 2).—Cells moderately large, length about twice the width, truncate-elliptic, semi-cells slightly depressed, the sides curved and somewhat inflated; the basal angles rounded; sinus linear; cells 39.9$\mu$ in length, 27.0$\mu$ in width; breadth of isthmus 7.6$\mu$.

Smith (1924) pp. 28 to 29. Taylor (1934) p. 261, Pl. 50, Fig. 7.

Only 7 specimens were found in culture. By cell size and form, they approached most closely *Cosmarium pseudopyramidatum* var. *lentiferum* W. R. Taylor (1934).

*Euglena viridis* Ehrenberg (Pl. 6, Fig. 9).—Cells actively swimming, spindle-form, with blunt anterior end, 16.2 to 16.9$\mu$ (14.0 to 18.0$\mu$) in width, 52.0 to 53.3$\mu$ (52.0 to 57.0$\mu$) in length; membrane delicate, flagellum as long as body, thread-like; nucleus located posteriorly; resting cells with thick walls.

Pascher and Lemmermann (1913) p. 127, Fig. 189.

**Summary**

1. Detmer's solution, merely natural water fortified especially by $Ca(NO_3)_2$ but with other added salts in smaller quantities, proved the best medium for culturing algae of five different media tried. It was employed exclusively in all the later cultures of the series made to determine what fresh

water algae remained viable after passing through the alimentary canal of a vegetarian fish.

2. The comparative amount and quality of algal residue in different portions of the alimentary canal of the gizzard shad *(Dorosoma cepedianum)* was due to variation of available algae present at the time of feeding and possibly also somewhat to the activity of the fish. Food intake must inevitably depend upon the varying phytoplankton in the immediate habitat of the fish. Detailed observations were made for fish collected where the conditions were different, but the species of algae obtained in cultures were in the main the same assemblage in every instance.

3. The species and varieties of viable algae are practically the same throughout the alimentary canal. It may therefore be concluded that whatever species are quickly destroyed and digested are quite immediately effected near the mouth end of the alimentary canal. In this connection the large number of common genera that were not recovered at all in culture is significant. No specimens or only an insignificant number ever turned up in culture of any of the following groups always present in ordinary fresh water habitats: (a) Bacillariae, (b) Volvocaceae group, (c) *Dinobryon* of the Heterokontae, and (d) filamentous green algae.

4. There survived 30 species and varieties of Chlorophyceae; 12 species and varieties of Myxophyceae; 4 species of Bacillarieae; 2 species of Heterokontae; and 1 species of Euglenophyceae. The order Chlorococcales (Chlorophyceae) had the greatest number of viable algae. The Myxophyceae followed in the number of viable species. It seemed that cell wall modifications or rather special secretions resisted the digestive fluids of the fish. In the Bacillarieae, only 4 species were viable; the shell of the diatoms, although made of highly resistant silica, possesses microscopic pores which allow the digestive fluid to penetrate and kill the protoplasm inside. No viability was observed after 6 days of confinement of the ingested diatoms in the digestive tract.

5. More species and varieties of algae were viable in cultures when the food had not been confined in the alimentary canal of the fish longer than two days. Decrease in viability appears to be inversely proportional to length of confinement of food in the alimentary canal.

6. It has been shown experimentally that 1/3 of the algal species and varieties determined by Tiffany as contributing to the algal food of the gizzard shad might have been viable.

7. Certain highly resistant algae are capable of maintaining life even when subjected to a prolonged confinement in the digestive tract of the gizzard shad.

8. It was shown that although the form and measurement of some algae are considerably altered by such variation of environment as comes about in culture, still no serious problem in taxonomic determination results. Varia-

tion under ordinary culture conditions lies within the range of variation of the species as they exist under widely varying habitat conditions in nature.

9. As a whole, the investigation indicates that one of the sources of the selective increase of certain algae in nature and, conversely, of the decrease of others, is most probably through vegetarian fishes—*Dorosoma cepedianum* (Le Sueur) being one of them.

10. Selective elimination of the more desirable food species from the phytoplankton in overcrowded fish ponds may prove to be of economic as well as purely ecological interest.

## REFERENCES

ADAMSTONE, F. B. 1924—The Distribution and Economic Importance of the Bottom Fauna of Lake Nipigon. Univ. Toronto Stud. Biol. Ser. **25**:35-100, 4 Pls.

BOYER, C. S. 1916—The Diatomaceae of Philadelphia and Vicinity. Philadelphia.

BREDER, C. M., JR., AND D. R. CRAWFORD. 1922.—The Food of Certain Minnows. A Study of the Seasonal Dietary Cycle of Six Cyprinoids with Special Reference to Fish Culture. Zoologica, (New York) **2**:287-327, figs. 98-128.

BRISTOL, B. M. 1920—On the Alga-Flora of some Desiccated English Soils: an Important Factor in Soil Biology. Ann Bot. **34**:35-80, Pl. II, figs. 1-12.

CABLE, L. E. 1928—Food of Bullheads. Rep. U. S. Com. Fisheries, Washington, D. C., Part **1**:27-41.

CASSIDY, H., A. DOBKIN AND R. WETZEL. 1930—A Study of the Food of Three Fish Species from the Portage Lakes, Ohio. Ohio Journ. Sci. **30**:194-198.

CLEMENS, W. A. AND OTHERS. 1923—The Food of Lake Nipigon Fishes. Univ. Toronto Stud. Biol. Ser. **22**:173-188.

COYLE, E. E. 1930—The Algal Food of *Pimephales promelas*. Ohio Journ. Sci. **30**:23-35.

DERYKE, W. 1922—Foods of the Common Fishes of Winona Lake in Kosciusko County, Indiana. Div. of Fish and Game, Dept. Conservation, State Indiana, pp. 7-48.

FORBES, S. A. 1878—The Food of Illinois Fishes. Ill. State Lab. Nat. Hist. Bull. **2**:71-89.

FORBES, S. A. AND R. E. RICHARDSON. 1920—The Fishes of Illinois, 2nd Edition, pp. 45-47. Ill. State Lab. Nat. Hist. Sur., State Printers, Springfield, Ill.

FRED, E. B. AND S. A. WAKSMAN. 1928—Laboratory Manual of Microbiology, pp. 20-21. McGraw-Hill Book Company.

GEITLER, L. 1925—Cyanophyceae. In Pascher, A. Die Süsswasser-flora Deutschlands, Österreichs und der Schweiz. Heft 12. Gustav Fischer, Jena.

GOMONT, M. M. 1892—Monographie des Oscillariées. Ann. Sci. Nat. Septiéme Sér., Botanique, **16**:91-256, Pl. 1-7.

HEERING, W. 1914—Chlorophyceae 3. In Pascher, A. Die Süsswasser-flora Deutschlands, Österreichs und der Schweiz. Heft 6. Gustav Fischer, Jena.

LEMMERMANN, E., JOS. BRUNNTHALER UND A. PASCHER. 1915—Chlorophyceae 2. In Pascher, A. Die Süsswasser-flora Deutschlands, Österreichs und der Schweiz. Heft 5. Gustav Fischer, Jena.

NURNBERGER, P. K. 1928—A List of the Plant and Animal Food of some Fishes of Jay Cooke Park. Trans. Amer. Fish. Soc. **58**:175-177.

PASCHER, A. UND E. LEMMERMANN. 1913—Flagellatae 2. In Pascher, A. Die Süsswasser-flora Deutschlands, Österreichs und der Schweiz. Heft 2. Gustav Fischer, Jena.

———, J. SCHILLER UND W. MIGULA. 1925—Heterokontae, Phaeophyta, Rhodophyta, Charophyta. In Pascher, A. Die Süsswasser-flora Deutschlands, Österreichs und der Schweiz. Heft 11. Gustav Fischer, Jena.

PEARSE, A. S. 1918—The Food of the Shore Fishes of Certain Wisconsin Lakes. Bull. Bur. Fish., Washington, D. C., **35**:245-292.

SHAW, W. R. 1919—*Campbellosphaera*, a new genus of the Volvocaceae. Phil. Journ. Sci. **15**:493-520, Pl. 1-2, fig. 1.

SMITH, G. M. 1916—A Monograph of the Algal Genus *Scenedesmus*, based upon Pure Culture Studies. Trans. Wisc. Acad. Sci., Arts and Letters **18**:422-528, Pls. XXV-XXXIII, Figs. 1-208.

———1920—Phytoplankton of the Inland Lakes of Wisconsin. Part I, Myxophyceae, Phaeophyceae, Heterokontae, and Chlorophyceae exclusive of the Desmidiaceae. Wis. Geol. and Nat Hist. Sur., Bull. **57**(1):1-243, Pls. 1-51.

———1924—Phytoplankton of the Inland Lakes of Wisconsin. Part II, Desmidiaceae. Wis. Geol. and Nat. Hist. Sur., Bull. **57**(2);1-227, Pls. 52-88.

———1926—The Plankton Algae of the Okoboji Region. Trans. Am. Mic. Soc. **45**:156-233, Pls. 1-20.

———1933—Fresh-water Algae of the United States. McGraw-Hill Book Company.

SUNIER, A. L. J. 1922—Contribution to the Knowledge of the Natural History of the Marine Fish-Ponds of Batavia. Treubia **2**:157-400.

TAYLOR, W. R. 1934—The Fresh-water Algae of Newfoundland, Part I. Mich. Acad. Sci., Arts and Letters **19**:217-278, Pls. XLV-LVII.

TIFFANY, L. H. 1921—Algal Food of the Young Gizzard Shad. Ohio Journ. Sci. **21**:113-122.

———1922—Some Algal Statistics Gleaned from the Gizzard Shad. Science **56**: 285-286.

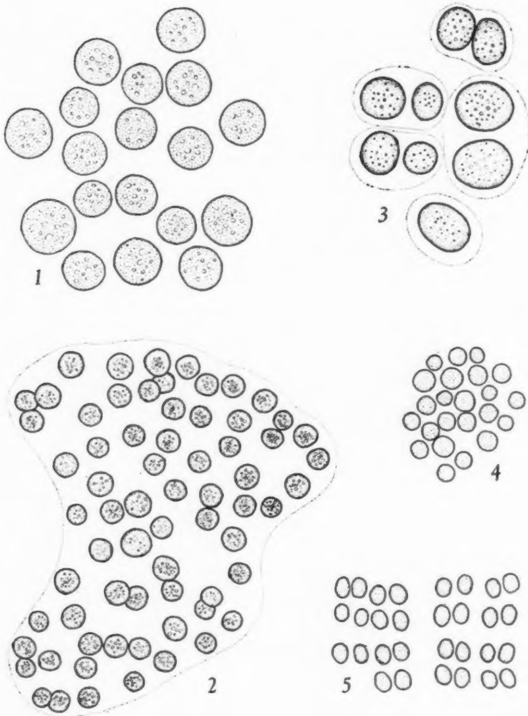
———1927—The Algal Collection of a Single Fish. Mich. Acad. Sci., Arts and Letters **6**:303-306.

———1938—Algae, the Grass of many Waters. pp. 1-171. Charles C. Thomas, Publisher.

TILDEN, J. 1910—Minnesota Algae. Vol. I. The Myxophyceae of North America. 328 pp., 20 Pls. Minneapolis.

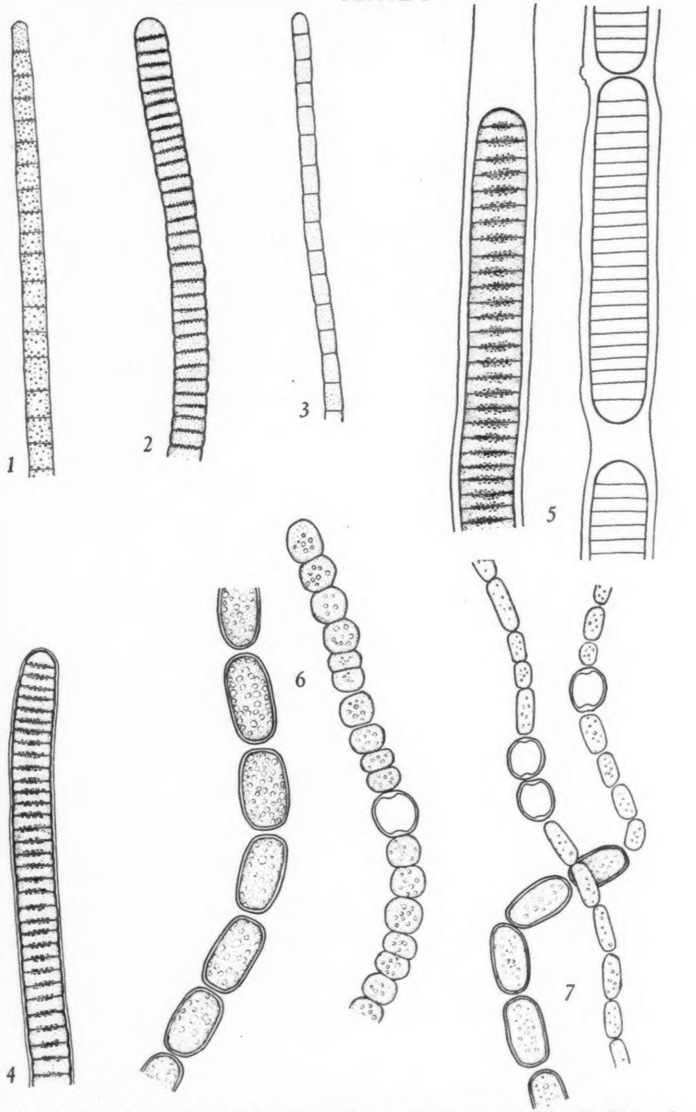
TURNER, C. L. 1921—Food of the Common Ohio Darters. Ohio Journ. Sci. **22**:41-62.

PLATE I



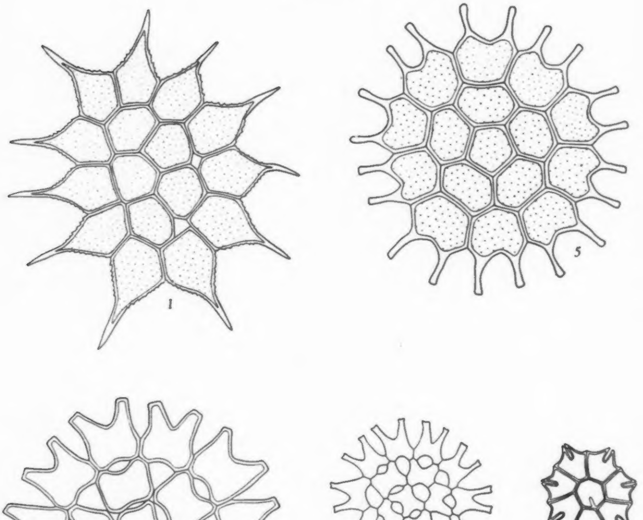

(1) Microcystis flos-aquae, x1330. (2) Microcystis aeruginosa, x1330. (3) Chroococcus minutus, x 1330. (4) Chroococcus dispersus var. minor, x1330. (5) Merismopedia punctata, x1330.

PLATE 2



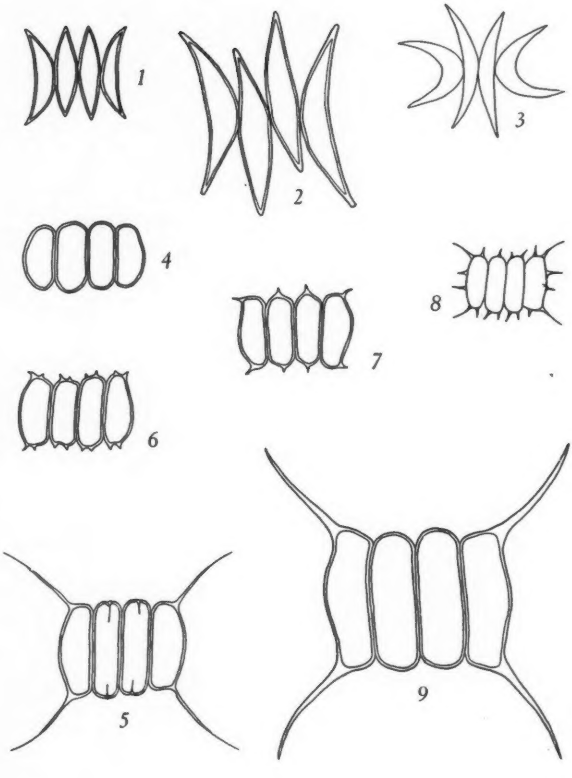

(1) Oscillatoria prolifica, x998. (2) Oscillatoria Grunowiana, x998. (3) Phormidium tenue, x 998. (4) Phormidium lucidum, x998. (5) Lyngbya aestuarii, x998. (6) Anabaena catenula, x 998. (7) Nostoc spongiaeforme, x998.

PLATE 3



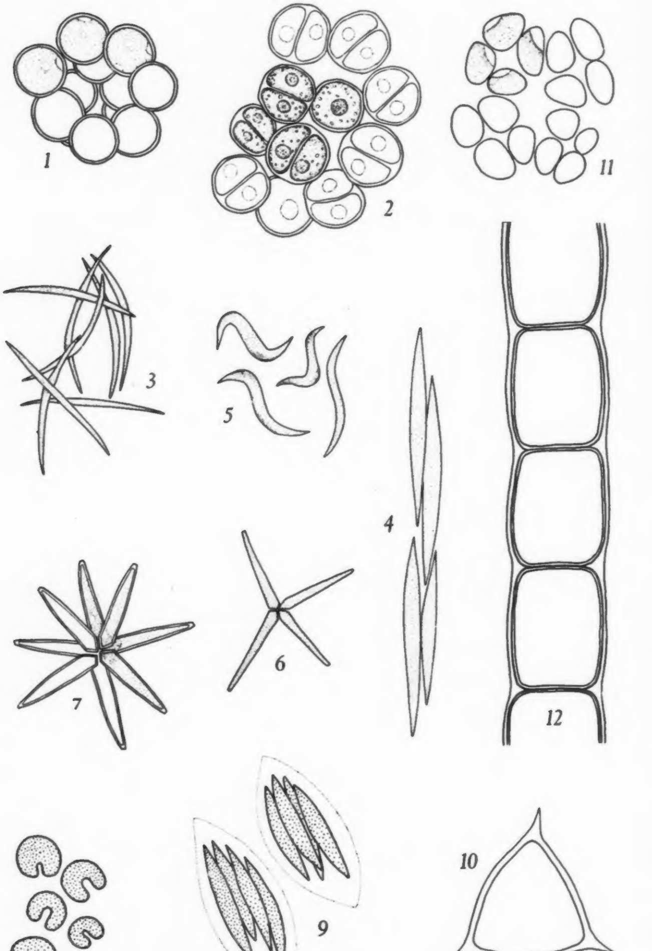
(1) Pediastrum simplex, x585. (2) Pediastrum duplex, x585. (3) Pediastrum duplex, var. rotundatum, x585. (4) Pediastrum integrum, x585. (5) Pediastrum Boryanum, x585. (6) Pediastrum biradiatum, x585. (7) Pediastrum tetras, x765.

PLATE 4



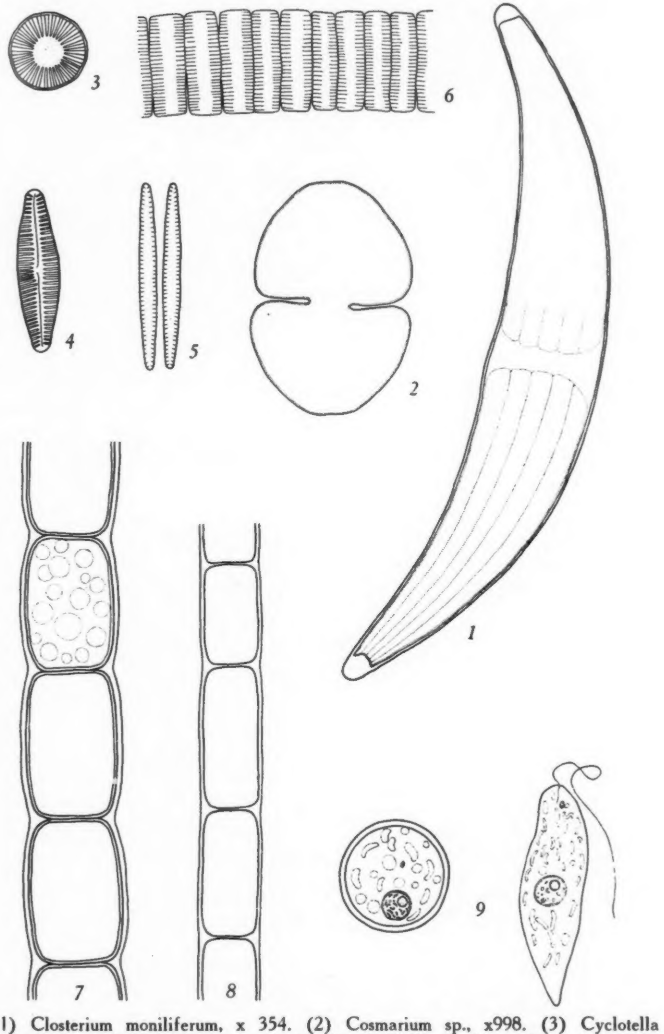

(1) Scenedesmus obliquus, x1330. (2) Scenedesmus dimorphus, x1330. (3) Scenedesmus acuminatus, x1330. (4) Scenedesmus bijugus, x1330. (5) Scenedesmus armatus, x1330. (6) Scenedesmus denticulatus, x 1330. (7) Scenedesmus longus, x1330. (8) Scenedesmus abundans, x1330. (9) Scenedesmus quadricaudus, x1330.

PLATE 5



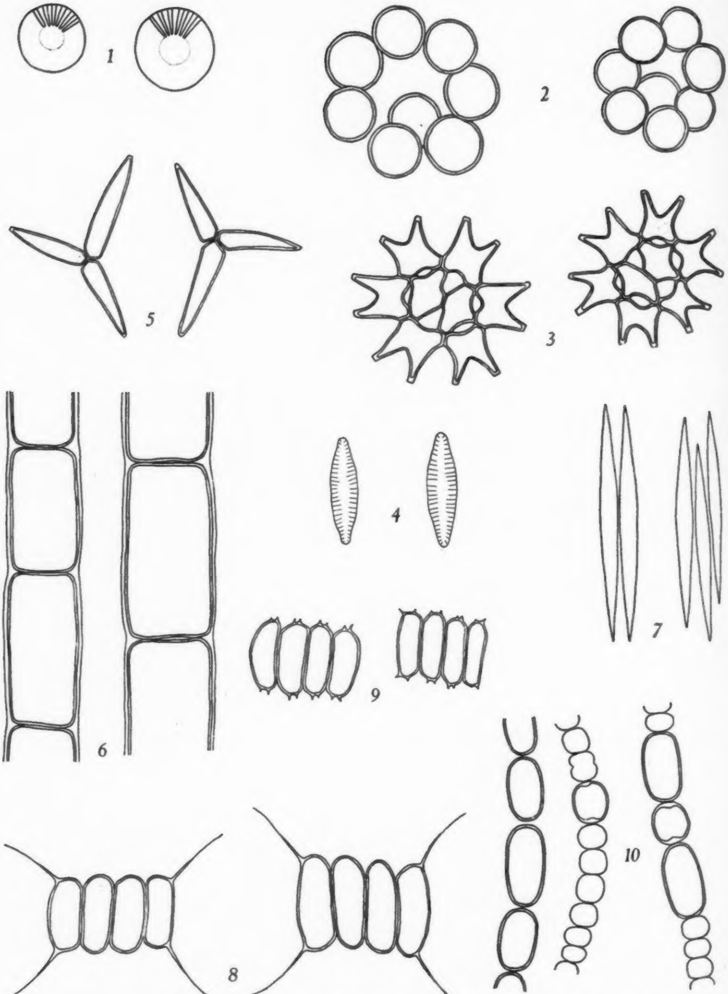

(1) Sphaerocystis Schroeteri, x998. (2). Protococcus viridis, x998. (3) Ankistrodesmus falcatus, x998. (4) Ankistrodesmus falcatus, var. tumidus, x 765. (5) Ankistrodesmus convolutus, x998. (6) Actinastrum gracillimum, x998. (7) Actinastrum Hantzschi, x998. (8) Kirchneriella obesa, x998. (9) Quadrigula lacustris, x998. (10) Tetraëdron trigonum, x998. (11) Crucigenia irregularis, x998. (12) Microspora floccosa, x998.

PLATE 6




(1) Closterium moniliferum, x 354. (2) Cosmarium sp., x998. (3) Cyclotella Meneghiniana, x998. (4) Navicula sp. indet. No. 1, x998. (5) Navicula sp. indet. No. 2, x998. (6) Diatoma sp., x998. (7) Bumilleria sicula, x998. (8) Tribonema cylindricum, x998. (9) Euglena viridis (left drawing, resting cell) x998.

## PLATE 7



(1) Cyclotella Meneghiniana, x998. (2) Sphaerocystis Schroeteri, x998. (3) Pediastrum duplex, x765. (4) Navicula sp. indet. No. 1, x765. (5) Actinastrum Hantzschi, x998. (6) Bumilleria sicula, x998. (7) Ankistrodesmus falcatus var. tumidus, x765. (8) Scenedesmus quadricaudus, x998. (9) Scenedesmus denticulatus, x998. (10) Anabaena catenula, x998.

Comparative drawings of ten kinds of algae grown in cool and warm rooms; left hand drawing, specimen from the cool room; right hand drawing, specimen from the warm room.

# A New Ant from the Great Smoky Mountains, Tennessee

A. C. Cole, Jr.

**Formica habrogyna** sp. nov.

*Holotype,* worker. (Cole collection No. 2285).

Total length, 6.0 mm.

Head, excluding mandibles, a little longer than broad, slightly broader behind than in front, with convex posterior and lateral borders. Clypeus carinate its entire length, the anterior border entire and angularly projecting, its median lobe large, very convex, abrubtly set off from the lateral portions and projecting abruptly from them in front. Frontal area triangular, broader than long, markedly depressed, its apical angle not as well marked as the basal angles. Frontal carinae short and strongly divergent. Frontal furrow faint but visible for a distance as great as the length of the frontal carinae. Frontal lobes sharply angular. Mandibles stout, strongly convex, 8-toothed. Antennal scapes slightly curved, rather stout, evenly thickened from base to apex, extending about one-third their length beyond the posterior corners of the head; funicular joints longer than broad, basal joints longer and narrower than apical joints, basal joint the longest, terminal joint nearly as long as the two preceding joints taken together and tapering toward the apex.

Thorax in profile rather long, not particularly robust. Pronotum broadly convex; promesonotal constriction distinct and breaks the promesonotal outline in profile; mesonotum convex, somewhat more so than the pronotum; mesoepinotal suture narrowly and rather shallowly impressed, base of depression flat and ascending anteriorly; epinotum rather narrow, higher than long, dorsal face broadly convex, posterior declivity almost straight and the angle between them well marked. Thorax rather stout when seen from above; pronotum appearing broad and very convex; mesonotum narrow, about one-half the width of the pronotum; apex of epinotum decidedly narrower than that of the mesonotum or pronotum, giving the appearance of a distinct blunt crest. Petiole with a rather blunt anterioventral lobe; scale wide, a little higher than the angle made by the two dorsal faces of the epinotum, with a convex anterior surface and a rather straight posterior surface; border blunt, broadly rounded and feebly produced upward in the middle. Legs long, with rather stout femora and tibiae. Gaster large, elliptical and somewhat pointed at the apex.

Opaque; mandibles, clypeus, frontal area and frons slightly shining; frons, vertex, thorax and petiole finely and densely shagreened; genae and gula feebly shagreened and more shining. Mandibles finely and longitudinally striate; clypeus very faintly covered with fine striae.

Erect hairs sparse; short and rather blunt; very short and sparse on gula, vertex, occiput and posteriolateral angles of head; longer, denser and more pointed on mandibles, frons and clypeus; absent from antennae; short and sparse on thorax, very sparse on venter and on pronotum, absent laterally, longer and denser on coxae but other leg segments naked. Apex of each mandible with a tuft of fine pointed hairs. Venter of petiole with a single cluster of dense and rather long hairs; apical border of scale with a row of sparse short hairs. Hairs on gaster more numerous than elsewhere, but very sparse laterally, shorter and more blunt than those on clypeus and frons. Pubescence fine, short and yellowish; much more abundant on gaster than elsewhere, and concealing the surface; sparse on epinotum; very sparse on remainder of thorax and on the head; dense on antennal scapes and funiculi.

Head and thorax Sandford's brown; legs and antennal funiculi somewhat darker; eyes and mandibular teeth black; mandibles dark reddish brown; gaster blackish brown No. 1, except the base which is reddish. Occipital region of head and apex of epinotum lightly infuscated.

*Paratype*, nest queen. (Cole collection No. 2285).

Total length, 5.9 mm.

Head very much like that of holotype, but smaller. Eyes strongly convex, with their outline extending beyond the side of the head when viewed from in front. Thorax, when seen from above, suboctagonal, narrower than the head, widest point a little anterior to the stubs of the fore wings: scutum a little longer than broad, subpentangular in outline; median anterior angle broadly rounded; anterior edge of scutellum feebly arcuate, the lateral projections rather broad, long and sharp at their tips; mesonotum narrow and broadly U-shaped. In profile, the suture between pronotum and scutum is distinct, so that the sharply sloping face of pronotum is well differentiated from the abruptly ascending face of the broadly convex scutum; metaepinotal suture shallow and rather broad; long descending face of epinotum concave near the base, the angle between it and the short convex upper surface broad and indistinct. Petiole with a rather blunt anterioventral lobe; base of petiolar scale very thick, apex narrow; apical border rather blunt, rounded and produced upward in the middle; anterior face of scale convex, posterior face rather flat. Legs shorter and a little stouter than those of holotype. Gaster ovoid, slender and pointed distally.

Sculpture much like that of holotype, but clypeus more feebly and less uniformly striate, and the entire body more shining, especially the scutum and scutellum. Hairs long, slender, pointed and numerous except on femora, tibiae, tarsi, genae, antennae, petiolar scale and most of pronotum and posterior declivity of epinotum, where they are very sparse or altogether absent; present on posterior corners of head. Pubescence yellow, very fine and sparse; more dense on gaster but does not obscure the shining surface.

Head and thorax russet, except compound eyes, ocelli, mandibles, palpi, wing stubs and legs; ocelli, mandibles, palpi, antennae, legs and wing stubs darker; compound eyes and mandibular teeth black. Gaster uniformly ochraceous tawny.

The type series consists of the following specimens: 67 workers and one nest queen (Cole collection No. 2285), Gatlinburg, Tennessee, April 10, 1938; 84 workers and one nest queen (No. 2566), 162 workers and one nest queen (No. 2567) and 92 workers and one nest queen (No. 2568), all from Gatlinburg, April 31, 1939; and 58 workers and one nest queen (No. 2590), Gatlinburg, May 14, 1939. All were collected by the author.

Both the holotype and the paratype queen used for the description are a part of collection No. 2285. This colony was a populous one and had its nest beneath several small rocks obscurely banked with plant debris. All the nests mentioned above were near the top of a rather steep, dry, grassy north-facing hillslope. In each nest the queen was found with the brood in a chamber about three inches below the surface. The workers are aggressive and eject formic acid when disturbed. Worker larvae and pupae were in all of the nests examined. All colonies were beneath rocks which were not imbedded in the soil. None of the nests had more than a scant supply of plant debris around it, and this was usually not discernible until after the rock had been removed. The elevation of the hillslope where the nests were found is approximately 1700 feet.

The holotype and a long series of paratypes are in the author's collection. One paratype queen and a series of paratype workers are to be deposited in the U. S. National Museum.

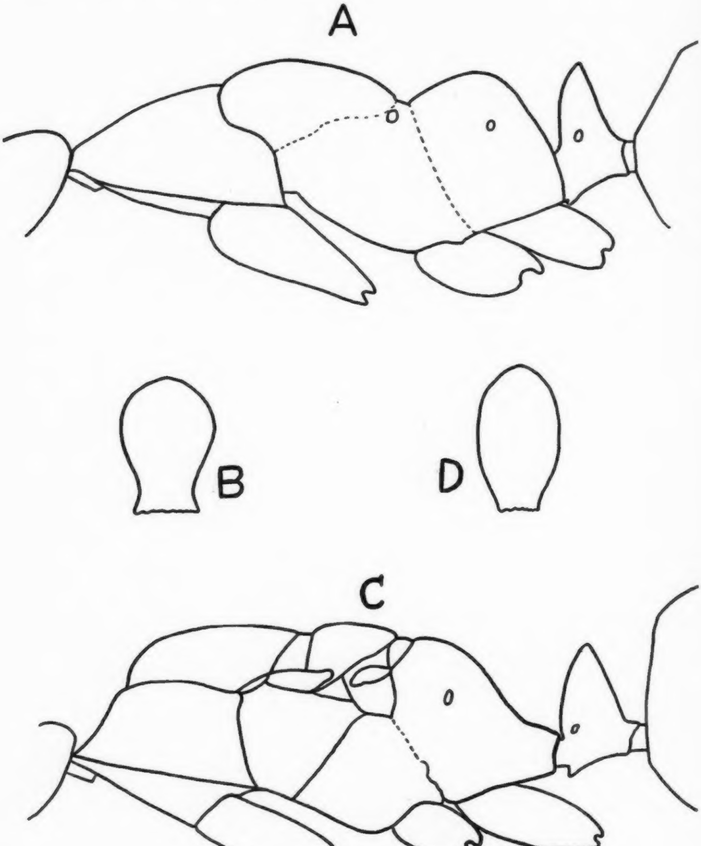
*Variation in paratype material.*—The paratype series of workers consists of 462 specimens. The total body length varies from 4.3 to 6.1 mm. A few of the workers have the apical border of the petiolar scale more rounded than that of the holotype. Many of the smaller workers have the head, pronotum and mesonotum infuscated, but in many other small workers the infuscation is absent. In some of the smaller workers the hairs on the gula are sparse or altogether absent. In other respects they are like the larger workers. Some of the larger workers have the occipital region and the epinotum lightly infuscated; others do not. On the average, the largest workers are of a somewhat brighter color than the small ones. The abundance and length of pilosity vary greatly among both the smaller and the larger workers.

The four paratype queens show little diversity from the paratype queen used as a basis for the description. Two of them have a little greater pilosity and in one the petiole is lightly infuscated.

*Affinities.*—The small size of the queen together with a lack of cephalic characters peculiar to the Sanguinea Group leave no doubt that this new species belongs in the Microgyna Group. In Wheeler's revision of the genus *Formica*, the workers and queens key out to *difficilis*, whose type locality is Virginia.[1] I have been able to compare workers of the new species with those of *difficilis* collected in Virginia by T. Pergande. The new species shows a

[1] *F. difficilis* has also been collected in the Black Mountains of North Carolina and in various localities in New Jersey and New York.

close relationship to *difficilis* in many respects, chiefly in the cephalic characters and in most of the sculpture. The worker differs from that of *diffiicilis*, however, in the following respects: The median clypeal lobe is more convex and less markedly carinate, the mesoepinotal suture is deeper, the epinotum is not as sharply angular in profile, hairs are present on the apical border of the petiolar scale, the color of the head and thorax is darker and erect hairs are more numerous, longer and less blunt.




*Formica habrogyna* sp. nov. A, Holotype (worker), showing contours of the thorax; B, anterior face of petiolar scale of holotype; C, paratype (queen), showing contours of the thorax; D, anterior face of petiolar scale of paratype queen.

I have not been able to examine cotypes of the variety consocians Wheeler, which are supposed to differ from the typical[1] *difficilis* in their greater pilosity. Because of the great variation in pilosity among the workers of my paratype series, I felt considerable doubt as to the validity of *consocians*, since *consocians* is based chiefly upon this character. As regards the matter, Dr. M. R. Smith wrote me the following opinion which I quote, "I have not seen cotypes of Wheeler's *consocians* nor have I any authentically determined specimens. Since the variety is based almost entirely on length and abundance of pilosity, and our specimens in the museum seem to vary considerably in this respect, I am not sure whether the variety has any validity or not."

Through the kindness of Dr. Smith and the U. S. National Museum, I have been privileged to examine two females of *difficilis*. As regards the status of these specimens, I quote from Dr. Smith's letter to me: "I cannot be sure whether these are types or not. Emery did not cite the specific type locality for the species, simply stating that he had received all three castes of the species from New Jersey and Virginia. In our collections there are specimens from Caldwell, N. J. marked 'collections of Theodore Pergande' and attached to these is a hand written label '*Formica difficilis* Emery; det. Emery; types'. Unfortunately there are only two queens in this series. There are also in the collection a number of series of specimens of *difficilis*, some bearing only the label 'Va.,' and others 'Rossyl, Va.' None of these from Va. have anything to indicate they are type specimens and only the Rossyln specimens are represented by queens, hence I am sending you two queens of the Rossyln series."

Upon comparing the paratype queens of the new species with the two females of *difficilis* loaned me I have found several distinct differences which I enumerate as follows: The length of the entire body is greater than that of *difficilis*, the thorax is decidedly narrower, the apical tooth of the mandibles is shorter and more blunt, the head is smaller, the thorax seen from above is narrower and hence decidedly more slender, the scutum is more uniformly convex, the petiolar scale is narrower and its apex is less broadly rounded, the pubescence on the body is much more sparse and does not obscure the surface, the gaster is much narrower and the entire body is darker and not concolorous.

Descriptions and comparisons are based upon dried alcoholic specimens. Colors of all major body regions are those determined by comparison with the plates in Ridgway's, "Color Standards and Color Nomenclature." Colors of small parts are those of the writer's conception and were determined at a magnification of 30 diameters.

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# Pseudogynes of Formica neogagates Emery

A. C. Cole, Jr.

While collecting ants near Albuquerque, New Mexico, May 20, 1932, the writer took a series of 26 specimens of *Formica neogagates* Emery from a small nest in an area of grass and yucca. There was a small, earthen, grass-covered mound over the nest. The workers were not numerous and the queen was not found. In the series collected the writer discovered 6 distinct pseudogynes. These are so markedly different from the normal workers that it seems advisable to give them brief mention.

The late Dr. W. M. Wheeler interpreted the pseudogyne as a "workerlike form with enlarged mesonotum and sometimes traces of other sclerites of the female, but without wings or very rarely with wing vestages."[1] He believed that pseudogynes in nests of *Formica* were produced by Lomechusine beetles in the colony. They are supposedly formed from female larvae which have been neglected by the workers and "left unfed after they have passed the stage at which such treatment would lead to the formation of workers."[2] This is an expression of the trophogenic interpretation of caste formation. Although the matter of caste determination has as yet been unsolved and is still debatable, it is such studies as this one of pseudogynes which seem to indicate a trophogenic rather than a blastogenic determinant for the various female castes of ants.

One of these pseudogynes of *neogagates* (Fig. 1) differs from the normal worker as follows: The thorax is greatly enlarged. In profile, the anterior face of the pronotum is steep, and the mesonotum is large and convex. The anterior face of the long scutum is very convex and leads into the almost flat uppermost surface. The scutellum is well developed, being about one-third as long as the scutum. There is only a faint dorsal impression between the scutum and scutellum. The posterior declivity of the scutellum is very sharp, forming almost a right angle with the horizontal axis of the body, and there is a deep but rather narrow impression between it and the narrow but distinct metanotum. The epinotum is much lower than the mesonotum but only very slightly lower than the metanotum; its dorsal surface is faintly and broadly convex and its posterior declivity is rather steep, the two forming a broad obtuse angle at their juncture. There are no vestages of wings.

Seen from above, the pronotum is broadly convex and its sides are flattened. The mesonotum is ovoid and narrower than the pronotum, being

[1] Wheeler, W. M., *Ants; their Structure, Development and Behavior*. Columbia Univ. Press, 1926, p. 96.

[2] *Ibid.*, p. 408.

widest just a little anterior to its union with the lateral surfaces of the pronotum. The scutellum is subtriangular; its dorso-anterior angle is sharply acute and its posterior dorsal border is broadly convex. The metanotum is narrow. The epinotum is rather flat laterally, as broad as the scutum and as broad as high.

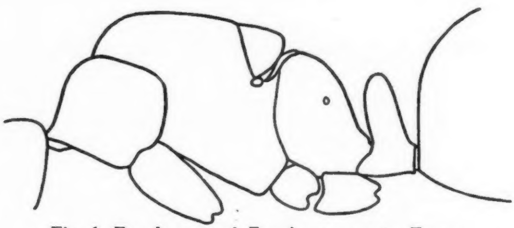

Fig. 1. Pseudogynes of *Formica neogagates* Emery.

Two specimens vary from this description as follows: The scutum is much more convex, so that the thorax in profile has a very decided arched appearance. There is no evidence of a suture dividing the mesonotum into a scutum and a scutellum, and there is no metanotum. The mesoepinotal suture is deep and rather broad, and the epinotum is much lower than the mesonotum. Among all the pseudogynes, the curvature of the lateral thoracic sutures varies considerably. Two specimens exhibit a narrower epinotum in profile than does the one described and figured. This results from a rather straight lateral mesoepinotal suture. In two specimens the lateral boundaries of the scutum are defined by faint sutures. In another specimen the scutum is more convex; hence the impression between the scutum and the scutellum is more pronounced. The thorax of each pseudogyne is reddish brown with doral infuscation. This condition of color also prevails among some of the normal major workers. Each pseudogyne has a body length comparable to that of a major worker.

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# Fluctuations in Biotic Communities, V.

## Aspection in a Mixed-Grass Prairie in Central Oklahoma*

J. Richard Carpenter

As representative of the south-central mixed-grass prairies a large cattle range in McClain county, Oklahoma (R. 4 W., T. 8 N., sec. 12), near the University of Oklahoma was selected and a study made of the ecology of its plants and animals. A consideration of the affiliations of the community found here with the remainder of the mixed-grass prairie community is included in a separate study dealing with the ecology of the entire grassland biome (Carpenter, 1939a). The area studied in Oklahoma, known locally as "Johnson's Pasture," has been somewhat overgrazed in the past, and burnings in the spring have been frequent. Grazing and fire have contributed to severe gulleying in the ravines and according to local reports the general appearance of the ravines which cut into the upland has been greatly changed by grazing with a resulting invasion of trees and shrubs which were not present in their present-day abundance 50 years ago. Elsewhere an account of succession in these ravines has been given (Carpenter, 1937). It is apparent that the instability of the tension zone has been enhanced by increased grazing pressure with a disproportionate increase in erosion. Erosion in the upland, except in the vicinity of the heads of the ravines, has been confined to sheet erosion. The upland is dominated by mixed-prairie grasses for the most part and the aspect is typically that of prairie. The local distribution of the dominant grasses and the seasonal plants of the serotinal aspect has been described by Carpenter (1939b).

### The Perennial Nucleus

As in most areas, the larger animal forms have been removed from the region. Reports from the wolf trapper of the U. S. Biological Survey operating in the vicinity in 1935 indicated that the Oklahoma wolf *(Canis frustror —rufus**)* is still present in the region and is being trapped at the present time. Recent trapping has also shown that the following forms are relatively abundant in their respective habitats: *Peromyscus* in ravine edges and prairie, cottonrats *(Sigmodon hispidus texianus)* in ungrazed prairie and ravines, pack rats *(Neotoma floridana baileyi)* in ravines where there is undergrowth and

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* Based on a portion of a thesis submitted to the Faculty of the Graduate School of the University of Oklahoma in partial fulfillment of the requirement for the degree of Doctor of Philosophy, 1939. Contribution from the Zoological Laboratories, University of Oklahoma, no. 201.

** Goldman, in his recent revision of the genus, considers that *frustror* is to be included under the name *rufus*, a form formerly considered to be more southern.

thicket available nearby. Pocket gophers *(Geomys lutescens)* are locally abundant where there is a deep soil and a large prairie-dog town is in the area. Evidences of the presence of shrews are somewhat uncertain but they may be here. Tracks similar to those of racoon have been seen several times in soft soil in ravine bottoms, but no other indications have been evident. Both the California jackrabbit *(Lepus californicus melanotis)* and the cottontail rabbit *(Sylvilagus floridanus alacer)* are present in numbers, the latter being present in both prairie and ravine, showing but little apparent selection of habitat. The former has never been seen by the writer in a wooded ravine except in flight after disturbance. All of the native hawks are present and absent sporadically, the number varying greatly from day to day. The same may be said of many of the insectivorous birds: the meadow lark, prairie horned lark, several sparrows, as well as a number of ravine birds, being present in one week's observations and absent at the next. It may be assumed that these birds range widely. As a rule ravine birds are rather restricted to wooded areas and are but rarely seen in the prairie, even in flying from one wooded ravine to another; the mourning dove is perhaps an exception. Agricultural pests (*Lygus pratensis, Blissus leucopteris, Diabrotica* spp., etc.) are present in very small numbers if at all and cannot be said to have any great influence on the community; this is taken as an indication of approach to natural conditions.

## Aspection in Normal Areas

Observations and collections of seasonal numbers of animals were begun on September 26, 1933, and continued for 22 months, a total of 56 quantitative collections being made. Observations were made at stations on high, sloping, and low prairie, and in wooded ravines (the latter collections have already been reported upon; Carpenter, 1937). It should be noted that the dryness of the summer of 1934 had a profound influence on the activity, developmental rate, and viability of many of the forms and a comparison with collections of other years with respect to these effects is necessary, since the size of the total populations was not profoundly changed. The quantitative data presented in the tables appended to this report are based on collections made with 100 sweeps of an insect net.

Aspection in all cases began earlier in the year in lower and sloping areas than in the high prairie, but proceeded more rapidly in the latter once activity had begun. Prevernal activity in the wooded ravines began as early as March 10 (1934) while the prairie itself showed little change in aspect until three weeks later. On March 10, however, a few grasshoppers and noctuids were active in the sloping prairie stations. Warm days which followed brought out a few more forms in the more protected areas, but these were again driven back into hibernation or killed by the heavy freezes of late March. On March 17 a great portion of the area under study was burned over and from that time on collections were made in both the burned and non-burned areas. A comparison of the two areas is made below. Beginning March 29 vernal forms again began to appear, especially noctuids and many Diptera.

On April 8, monarch butterflies *(Anosia plexippus—Danais (Danaus) archippus)* appeared and continued in fluctuating abundance until October 31. The vernal period closed about April 27 in sloping areas but somewhat earlier than this in the higher upland.

More characteristic of the estival period were the Hemiptera and Coleoptera which had been increasing in numbers during the vernal period, as well as the aeschniids which ranged in from the ravines. Here also was the beginning of the period of conspicuous activity of the reptiles of the area: *Terrapene ornata, Pituophis s. sayi, Phrynosoma cornutum,* and several other lizards. The numbers of Orthoptera and robber flies likewise reached their peak of abundance during this period which was also the time of anthesis for the dominant grasses and for *Opuntia.*

The late estival and the serotinal periods (the latter beginning about July 29) were characterized by a lack of the soft bodied insects and those dependent on succulent leaves for food—notably the Diptera, Hemiptera, and to some extent Homoptera and, secondarily, spiders, since the latter's food is primarily the smaller succulent-feeding soft-bodied forms. After the rains (the week of August 20) many of the early summer components of the population returned and apparently in some cases a second brood of the insects appeared. The "second generation" forms fell into the autumnal sociation and were mostly Coleoptera, Diptera, and Homoptera, but predominantly the latter. Pierids were active during late autumn and the bulk of the invertebrate population ceased activity after November 24.

The general pattern of insect composition in aspection was therefore somewhat different from that reported by Shackleford (1931, 1935) and Fletcher (1930) for their respective areas in Oklahoma and Texas, but the difference was no doubt due in no small degree to the unusual seasonal distribution of rainfall. There is more agreement with Beed's (1936) study of a mixed-grass prairie in Nebraska, also made in the summer of 1934.

The details of aspection in this area are expressed in tabular form for the subdominant (seasonal) plants in table 1 and for the influential arthropod groups in tables 2 and 3. An outline of the structure of the animal components (the presociation) of this community is included in parts 1-3 of the appendix which has been placed at the end of the paper because of the length of the species lists.

The low prairie station which was used was at the base of a gently sloping hill and at the junction of two non-wooded ravines. The dominant plants were exclusively grasses, *Andropogon furcatus* and *A. scoparius* predominating, with but few forbs. During the extremely dry summer of 1934 the grasses remained green at this station. While physiographic and microclimatic differences exist sufficiently to distinguish this station very sharply from the stations on the upper slopes, a large number of species of the upper areas was found here and these are indicated by an asterisk (*) in appendix

3. Several species found in the prairies of Illinois and other more eastern states were present as would be expected from the moist nature of the habitat.

In the relatively undisturbed prairie areas, i.e., those having been grazed but not burned for several years and as represented by the three stations used, certain forms were found to be common in high and sloping prairie stations and hence were considered as truly characteristic and binding forms for the seasonal sociations in the climatic prairie in 1934. They are listed in app. 4.

### Aspection in Burned Prairie

As mentioned above, on March 17 a great portion of the prairie area was burned and after that date collections and observations were made in stations of both areas. There was no apparent prevernal activity on the part of either plants or animals in the burned area until April 14 when the first forms began to appear. The vernal period apparently lasted several weeks later here than in the unburned stations, but the succeeding periods essentially coincided with those of the unburned areas. Quantitative data regarding the seasonal abundance of invertebrates are presented in tables 5 and 6; the qualitative composition of the two unburned stations is presented in app. 5 and 6.

### The Effects of Burning

The effects of fire on prairie composition is a vital problem to the economic ecologist; the benefit (if any) to the range by burning is still an open question. Studies on the subject have been made by Aldous (1934), Hensel (1923), Pickford (1932), Rice (1931) and others, but the only general conclusion which may be drawn is that fire does not retard a community in seral development, probably creates a minor plagiosere (cf. Tansley, 1935, p. 293) which, if undisturbed, may or may not develop back to the original condition.

A comparative analysis of the composition of the insect population under burned and non-burned conditions is given in app. 3 and 4.

For the prairie at large in McClain county (i.e., as represented by the stations used) the following consistent response*** to burning was observed:

K: *Chlorotettix unicolor, Œcanthus nigricornis argentatus, Ortholomus scolopax, Xerophloea viridis, Idiocerus crataegi, Syrbula admirabilis, Orphulella pelidna, Melanoplus bivittatus, Chaetocnema denticulata, Mordellistena lutea, Epitrix brevis, Onychobaris pectorosa, Haltica bimarginata, Pachybrachys morosus.*

+: *Campylenchia latipes, Driotura robusta, Lygus pratensis, Melanoplus confusus, Boopedon* sp., *Ageneotettix deorum, Chalcoides helixnes.*

—: *Mormidea lugens, Peribalis limbolarius, Stictocephala lutea, Deltocephalus sandersi, Chortophaga viridifasciata, Haltica bimarginata.*

The increase of xeric conditions through burning in the sloping prairie stations made for an increase of high prairie species or an increase in the

*** "K": species present under both burned and non-burned conditions; "+": species added through burning; and "—": species lost through burning.

numbers of some of the species already present. Notable among the former were *Solubea pugnax, Vanduzea arquata,* and among the latter, *Ortholomus scolopax, Thyanta custator, Œcanthus nigricornis argentatus, Mecidea longula, Deltocephalus configuratus.* This addition in both physiographic levels was very apparent among the Hemiptera and Homoptera, but not very common among the Orthoptera. For the Coleoptera the effect of the burning was to cause the species to occur in smaller numbers and later in the season as a rule, although certain species stood their ground and had little change after subjected to the conditions following burning; a notable exception was *Pachybrachys morosus* which increased in number and occurred earlier in the season; *Mordellistena lutea* decreased from two broods per year to a single generation. Beetles increasing in numbers were *Chaetocnema denticulata, Pachybrachys morosus, Onychobaris pectorosa,* and *Mordellistena lutea.* Species "holding their own" and not appreciably decreasing in numbers were *Haltica bimarginata, Hippodamia convergens, Pachybrachys morosus, Bruchus obtectus,* and *Collops quadrimaculatus.*

## Summary and Conclusions

1. As representative of the southern mixed-grass prairies an area in McClain county, Oklahoma, was studied from the standpoint of the aspectional phenomena of the subdominants and influents.

2. The community here was found to be an *Andropogon scoparius-Panicum oligosanthes* mixed-prairie community with local faciations of *Bouteloua gracilis* on the hill tops, *Manisuris cylindrica* on uplands and sloping prairie, *Andropogon furcatus* and *M. cylindrica* on low upland prairie, and *Bouteloua hirsuta* and *Amphiachyris dacunculoides* forming an erosion facies.

3. Aspection was studied from September 1933 through June 1935. The biotic seasons or aspects of 1934, as expressed by the seasonal organisms, were as follows: prevernal, March 29-April 21; vernal, April 21-May 26; estival, May 26 - July 8; serotinal, July 8 - September 7; autumnal; September 7 - November 30.

4. Seasonal activity on the part of the insects and spiders followed in general the fluctuation pattern characteristic of prairie areas with a major peak of invertebrate population abundance in the estival period, and a minor peak during the autumnal period, in spite of the extremely dry period of the summer.

5. Observations were likewise made in an area close by which had been burned during the previous spring. It was found that the invertebrate population here was greatly increased during both the estival and autumnal periods on burned high areas, while on burned sloping areas the population was slightly greater throughout the rest of the year. The taxonomic composition, however, was somewhat changed and study of the additions and deletions

of insect species under burn conditions showed that certain forms were indicators of a plagiosere resulting from burning.


## ACKNOWLEDGEMENTS

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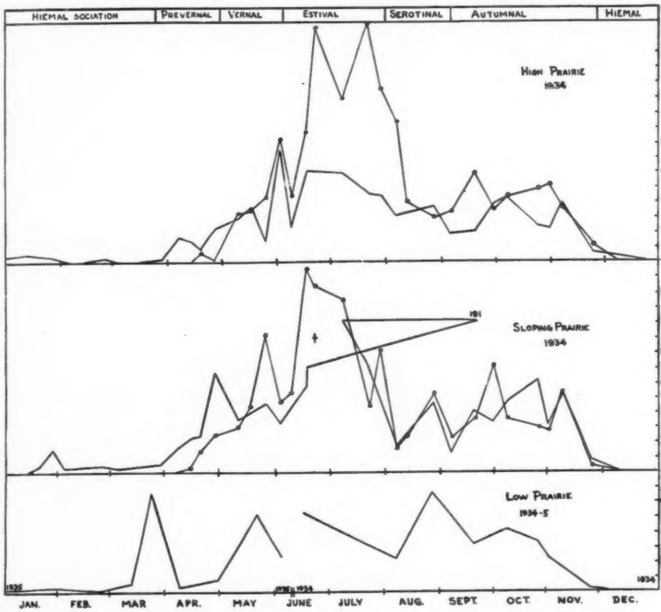


Fig. 1. Seasonal population fluctuations in three prairie stations in the Johnson's Pasture area, McClain county, Oklahoma, 1934. In the high and sloping prairie stations were set up in places which had been burned during the spring of 1934 and in those which had not been burned for at least several years. The date for the burned area are represented on the graph as (o............o) and for the non-burned as (. ............ .). The graph for the low prairie station represents collections made from June 1934 to May 1935.

## REFERENCES


ALDOUS, A. E. 1934—Effect of burning on Kansas bluestem pastures. Kans. Agr. Expt. Sta., Tech. Bull. **38**.

BEED, W. E. 1936—A preliminary study of the animal ecology of the Niobrara Game Preserve. Bull. Conserv. Dept., Univ. Nebr. **10**:1-33.

CARPENTER, J. R. 1936—Daily fluctuations in insect populations in the prairie-forest ecotone of North America. C. R. XIIe Congr. Int. Zool., Lisbonne, 1935. **2**:969-979.

———1937—Fluctuations in biotic communities, III. Aspection in a ravine sere in central Oklahoma. Ecology **18**:80-92.

———1939a—The grassland biome. (in preparation).

———1939b—Plant distribution in a mixed-grass prairie in central Oklahoma. (in preparation).

FLETCHER, R. K. 1930—A study of the insect fauna of Brazos county, Texas, with special reference to the Cicadellidae. Ann. Ent. Soc. Am. **23**:33-54.

HEFLEY, H. M. 1927—A preliminary report on the seasonal aspects of six habitats near Norman, Okla. Proc. Okla. Acad. Sci. **6**:24.

———1937—Ecological studies on the Canadian river floodplain in Cleveland county, Oklahoma. Ecol. Monogr. **7**:345-402.

HENSEL, R. L. 1923—Recent studies on the effect of burning on grassland vegetation. Jour. Agr. Res. **23**:631-647.

PICKFORD, G. D. 1932—Influence of continued heavy grazing and promiscuous burning on spring-fall ranges in Utah. Ecology **13**:159-172.

RICE, L. A. 1932—Effect of fire on prairie animal communities. Ecology **8**:392-401.

SHACKLEFORD, M. W. 1929—Animal communities of an Illinois prairie. Ecology **10**:126-154.

———1931—Autumnal herb societies of an Oklahoma prairie in 1927, 1928, and 1930. Proc. Okla. Acad. Sci. **11**:13-14.

———1935—Seasonal variations in the invertebrate population of a central Oklahoma prairie, November, 1933 to November, 1934. Proc. Okla. Acad. Sci. **15**:69-72.

——— AND M. J. BROWN. 1929—A comparison of the autumnal society of prairie invertebrates and of coincident weather conditions in 1927 and 1928. Proc. Okla. Acad. Sci. **9**:20.

TANSLEY, A. G. 1935—The use and abuse of vegetational concepts and terms. Ecology **16**:284-307.


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TABLE 1. Aspection of plants in McClain county, Oklahoma, Prairie.

| Seasonal Sociations | Prevernal | | | | Vernal | | | | Estival | | | | Serot | | Aut'mn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | March | April | | | | May | | | June | | | July | | September | | |
| 1934 | 29 | 8 | 14 | 21 | 27 | 10 | 17 | 26 | 2 | 8 | 17 | 8 | 29 | 7 | 19 | 30 |
| *Antennaria plantaginfolia* | x | x | | | | | | | | | | | | | | |
| *Lithospermum angustifolium* | x | x | x | | | | | | | | | | | | | |
| *Anemone caroliniana* | x | x | x | x | x | | x | | | | | | | | | |
| *Viola pedata* | | x | x | | | | | | | | | | | | | |
| *Nothoscordum bivalve* | | x | x | x | | | | | | | | | | | | |
| *Houstonia minima* | | | x | | x | | | | | | | | | | | |
| *Lesquerella ovalifolia* | | | x | | x | | x | | | | | | | | | |
| *Actinea linearifolia* | | | x | x | x | x | x | x | | | | | | | | |
| *Oxalis violacea* | | | | x | x | | | | | | | | | | | |
| *Callirhoë involucrata* | | | | | x | x | | | | | | | | | | |
| *Linaria canadensis* | | | | | x | | x | | | | | | | | | |
| *Sisyrinchium gramineum* | | | | | x | x | x | x | | | | | | | | |
| *Pyrrhopappus grandiflorus* | | | | | x | x | x | x | | | | | | | | |
| *Oxytropis Lambertii* | | | | | x | x | x | x | | | | | | | | |
| *Shrankia* sp. | | | | | x | x | | x | | | | | | | | |
| *Allium mutabile* | | | | | x | x | x | | x | | | | | | | |
| *Oenothera laciniatum* | | | | | x | x | | x | x | x | | | | | | |
| *Oenothera serrulata* | | | | | | x | x | | | | | x | | | | x |
| *Amorpha fruticosa* | | | | | | x | x | x | | x | | x | | x | | |
| *Specularia perfoliata* | | | | | | x | | x | x | | | | | | | |
| *Thelosperma trifidum* | | | | | | x | | | x | | | | | | | |
| *Lepidium virginicum* | | | | | | x | x | | x | x | | | | | | |
| *Stylingia sylvatica* | | | | | | x | x | x | | x | | | | | | |
| *Plantago occidentalis* | | | | | | | x | | x | | | | | | | |
| *Erigeron ramosus* | | | | | | | x | | x | | | | | | | |
| *Hymenopappus tenuifolius* | | | | | | | x | x | x | | | | | | | |
| *Delphinium Penardi* | | | | | | | x | x | x | | | | | | | |
| *Baptisia australis* | | | | | | | x | | | x | | | | | | |
| *Rudbeckia hirta* | | | | | | | x | | | | | x | | | | |
| *Psoralea tenuiflora* | | | | | | | x | | | x | | | x | | x | |
| *Achillea lanulosa* | | | | | | | | x | x | | | | | | | |
| *Plantago Purshii* | | | | | | | | x | x | | | | | | | |
| *Psoralea floribunda* | | | | | | | | x | x | | | | | | | |
| *Baccharus* sp. | | | | | | | | x | x | | | | | | | |
| *Callirhoë pedata* | | | | | | | | x | x | | | | | | | |
| *Sabatia campestris* | | | | | | | | x | x | x | | | | | | |
| *Monarda dispersa* | | | | | | | | x | x | x | x | | | | | |
| *Gaillardia pulchella* | | | | | | | | | x | x | | | | | | |
| *Specularia leptocarpa* | | | | | | | | | x | x | | | | | | |
| *Melilotus alba* | | | | | | | | | x | x | | | | | | |
| *Petalostemon purpureum* | | | | | | | | | | x | x | | | | | |
| *Helianthus mollis* | | | | | | | | | | x | x | | | | | |
| *Euphorbia marginata* | | | | | | | | | | x | | x | | | | |
| *Erigeron annuus* | | | | | | | | | | x | | x | | | | |
| *Gaillardia fastigiata* | | | | | | | | | | | | x | | | | |
| *Cassia chamaecrista* | | | | | | | | | | | | x | | | x | |
| *Amphiachyris dracunculoides* | | | | | | | | | | | | x | | | x | x |
| *Euphorbia corollata* | | | | | | | | | | | | | x | | x | |
| *Chrysopsis pilosa* | | | | | | | | | | | | | x | | x | x |
| *Liatris squarrosa* | | | | | | | | | | | | | | x | x | x |
| *Liatris punctata* | | | | | | | | | | | | | | | x | x |

APPENDIX 1. The Presociation of High Prairie (Invertebrate Constituents).
(see table 2)

Perennial Nucleus:
Incidentals: *Homaemus aenifrons, Phalacrus politus, Argiope trifasciata.*

Prevernal Sociation:
Incidentals: *Oncometopia undata,* Grasshopper nymphs.

Vernal Sociation:
Influents: *Strongylocoris stygicus, Solubea pugnax, Cymus virescens, Idiocerus crataegi, Stictocephala lutea, Haltica bimarginata.*

Incidentals: *Macropsis basalis, Bruchomorpha dorsata, Ortholomus jamaicensis, Chaetocnema denticulata, Mordellistena* sp., *Apion pennsylvanicum, Epitrix brevis, Hippodamia convergens, Onychobaris pectorosa, Collops quadrimaculatus, Colaspis favosa.*

Estival Sociation:
Influents: *Solubea pugnax, Chlorotettix unicolor,* Grasshopper nymphs, *Œcanthus nigricornus argentatus, Stictocephala lutea.*

Incidentals: *Ortholomus scolopax, Thyanta custator, Mormidea lugens, Gypona octolineata, Peribalus limbolarius, Galgupha nitiduloides, Epitrix brevis, Bruchus obtectus, Phyllodecta vittilina, Trox* sp.

Transition to the Serotinal Sociation:
Influents: *Mecidea longula,* grasshopper nymphs.
Incidentals: *Sinea diadema, Stictocephala lutea, Mygodenia serripes.*

Serotinal Sociation:
Influents: *Idiocerus crataegi, Syrbula admirabilis, Orphulella pelidna, Mermeria maculipennis, M. neomexicana, Syrbula fuscovittata.*

Incidentals: *Vanduzea arquata, Oliarus vittatus, Campylacantha olivacea, Melanoplus bivittatus, M. scudderi, Onychobaris pectorosa.*

Autumnal Sociation:
Influents: *Idiocerus crataegi, Ortholomus scolopax, Thyanta custator, Cymus virescens.*
Incidentals: *Catonia pumila, Calcoris norvegicus, Deltocephalus configuratus, D. sandersi, Xerophloea viridis, Orphulella pelidna, Mermiria neomexicana. Chortophaga viridifasciata, Pachybrachys morosus.*

APPENDIX 2. The Presociation of Sloping Prairie (Invertebrate Constituents)
(see table 3)

Perennial nucleus:
Incidentals: *Phalacrus politus, Epitrix brevis, Schistocerca* sp.

Hiemal Sociation:
Incidentals: *Draeculacephala reticulata, Aphodius servus.*

Prevernal Sociation:
Influents: *Empoasca radiata.*

Incidentals: *Euscelis obscurinervus, Thyanta custator, Xerophloea viridis, Bruchus obtectus, Dorytomus squamosus, Lepidophorus* sp.

Vernal Sociation:
Influents: *Mormidea lugens, Ortholomus jamaicensis, Macropsis basalis, Cymus virescens, Strongylocoris stygicus, Melanoplus bivittatus, Mermiria neomexicana,* Grasshopper nymphs, *Epicaerus formidulosus.*

Incidentals: *Adelphocoris rapidus, Deltocephalus configuratus, Sinea diadema, Ortholomus scolopax, Chariesterus antennator, Graphocephala coccinea, Phlepsius truncatus, Chalepus nervosa, Chaetocnema denticulata, Epicauta pennsylvanica, Haltica bimarginata, Mordellistena lutea, Anthonomus nigrinus, Onycho-*

*baris pectorosa, Collops quadrimaculatus, Cylindrocopturus nanulus, Stictocephala lutea.*

Estival Sociation:

Influents: *Mormidea lugens, Scolops spurcus, Peribalus limbolarius, Œcanthus nigricornis argentatus, Haltica bimarginata, Graphops varians.*

Incidentals: *Stictocephala lutea, Xerophloea viridis, Homaemus aenifrons, Megalotomus quinquespinosus, Deltocephalus configuratus, Catonia pumila, Onychobaris pectorosa, Mordellistena lutea, Chaetocnema denticulata, Pachybrachys hepaticus.*

Transitional to the Serotinal Sociation:

Influents: *Deltocephalus sandersi, Chlorotettix unicolor, Sinea diadema.*

Incidental: *Oncometopia undata.*

Serotinal Sociation:

Influents: *Idiocerus crataegi, Homaemus aenifrons, Syrbula admirabilis, Melanoplus bivittatus, Ophulella pelidna, Mermiria maculipennis.*

Incidentals: *Thyanta custator, Mecidea longula, Xerophloea viridis, Dissosteira carolina, Mermiria neomexicana, Syrbula fuscovittata, Pachybrachys morosus.*

Autumnal Sociation:

Influents: *Idiocerus crataegi, Cymus virescens, Stictocephala lutea, Peribalus limbolarius, Syrbula admirabilis, Ophulella pelidna.*

Incidentals: *Deltocephalus sandersi, Nabis ferus, Syrbula fuscovittata.*

APPENDIX 3. The Presocies of the Low Prairie (Invertebrate Constituents) (see table 4)

Perennial Nucleus:

Influents: *Idiocerus crataegi**.

Hiemal Socies:

Incidentals: *Paria sexnotata, Chlorotettix viridis, Homaemus aenifrons.*

Prevernal Socies:

Influents: *Chrysopa* sp.

Incidentals: *Deltocephalus inflatus, Hippodamia convergens, Epicaerus formidulosus, Mordella* sp., *Dicromorpha viridis.*

Vernal Socies:

Influents: *Deltocephalus inflatus, Epicaerus formidulosus, Deltocephalus sandersi**, *Typophorus canellus, Chortophaga viridifasciata.*

Incidentals: *Conocephalus strictus, Campylacantha olivacea, Chlorotettix unicolor, Pachybrachys morosus, Lygaeus kalmii, Leiobunum vittatum, Zygogramma* sp., *Lygus pratensis.*

Estival Socies:

Influents: *Melanoplus bivittatus,** *Solubea pugnax, Conocephalus strictus,** *Pediodectes haldmanii,** *Scolops spurcus, Campylacantha olivacea.*

Incidentals: *Peribalis limbolarius, Chariesterus antennator, Mormidea lugens.**

Serotinal Socies:

Influents: *Melanoplus bivittatus, Scolops spurcus, Orphulella pelidna,** *Euschistus variolarius.*

Incidentals: *Chlorotettix unicolor, Macropsis basalis, Mermiria neomexicana.**

Autumnal Socies:

Influents: *Orphulella pelidna, Œcanthus nigricornis argentatus,** *Cymus virescens, Argiope trifasciata.*

Incidentals: *Melanoplus bivittatus,** *Mermiria neomexicana,** *Micrutalis calva, Diapheromera (?velei), Syrbula fuscovittata,** *Pachybrachys morosus, Phalacrus*

* Species characteristic of the climatic (high and sloping) prairie.

Table 4. Data for collections made in burned areas, McClain Co., Okla.

| Socies | prevernal | | | vernal | | | estival | | | | | serotinal | | | | | autumnal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1934 | April | | | May | | | June | | | | July | | | August | | | September | | | October | | | Nov. | |
| A | 14 | 19 | 27 | 10 | 17 | 25 | 2 | 8 | 17 | 23 | 7 | 22 | 29 | 6 | 12 | 27 | 6 | 19 | 30 | 7 | 24 | 31 | 7 | 24 |
| *Hemiptera* | | | | 22 | 4 | 1 | 4 | 3 | 17 | 3 | | | | | | | | 2 | | 1 | 5 | 4 | 2 | |
| *Homoptera* | | 1 | | | 4 | 1 | 17 | 6 | 5 | 32 | 26 | 18 | 14 | 19 | 4 | 8 | | 12 | 20 | 24 | 40 | 36 | 30 | 2 |
| *Diptera* | | 3 | | | | 11 | | 3 | 1 | | | | | | | | 1 | | 2 | 4 | 2 | 6 | | 9 |
| *Coleoptera* | | | | 6 | 6 | 5 | 28 | 12 | 10 | 24 | | 2 | 1 | 2 | | 1 | | 3 | 4 | 4 | | 1 | | |
| *Orthoptera* | | | | 1 | 11 | 19 | 28 | 18 | 37 | 77 | 84 | 60 | 80 | 9 | 4 | 16 | 10 | 28 | 8 | | | | 1 | |
| *Spiders* | | 2 | | 1 | 2 | 5 | 6 | 2 | 10 | 21 | | 2 | 6 | 6 | 6 | | | 10 | 4 | | 1 | | | |
| *Hymenoptera* | | | | 1 | 8 | | | | 8 | | | 72 | 2 | 58 | 26 | 10 | 22 | 2 | 18 | 3 | 1 | 4 | 2 | |
| *Neuroptera* | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lepidoptera* | | | | | | 1 | | | | | | | | | | | | | | 2 | 1 | 4 | 2 | |
| Miscl. | | | | | | | | | | | | | 3 | | | | | | | | | | | |
| Total | 0 | 6 | 0 | 31 | 35 | 43 | 83 | 44 | 88 | 157 | 110 | 154 | 106 | 94 | 40 | 35 | 33 | 57 | 56 | 38 | 50 | 55 | 37 | 11 |
| B | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hemiptera* | | | | 4 | 1 | 5 | 1 | 3 | 27 | 15 | 2 | | | | | | | 4 | 2 | | | | 8 | 1 |
| *Homoptera* | | 3 | 6 | | 2 | 7 | 2 | | 6 | 4 | | | 10 | 2 | | 9 | 1 | 8 | 16 | 13 | 12 | 7 | 29 | |
| *Diptera* | | 2 | 14 | | 1 | 18 | 2 | 2 | 6 | | | | | | | | 1 | 4 | 6 | 3 | 10 | 12 | 5 | 4 |
| *Coleoptera* | | 2 | 2 | 16 | 6 | 4 | 3 | 3 | 2 | 3 | 8 | | 6 | 4 | | 3 | | | 2 | | 1 | | 2 | |
| *Orthoptera* | 3 | 2 | 2 | 3 | 11 | 53 | 27 | 31 | 66 | 98 | 92 | 46 | 48 | 8 | 20 | 30 | 20 | 16 | 24 | 7 | | | 4 | |
| *Spiders* | | 2 | | 6 | 6 | | 7 | 9 | 11 | 5 | 6 | 6 | 10 | 2 | 2 | 1 | 1 | | 1 | 7 | 2 | 2 | 3 | |
| *Hymenoptera* | | 2 | | 1 | 15 | | 5 | 5 | 6 | | | 3 | 6 | | 2 | 10 | | 1 | 8 | | | | | |
| *Neuroptera* | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| *Lepidoptera* | | | 1 | | 1 | 2 | | 1 | | | | | | | | | | 2 | 4 | 5 | 6 | | 1 | |
| Miscl. | | | | | | | | | | | 4 | | | | | | | | | | | | | |
| Total | 3 | 13 | 25 | 30 | 43 | 89 | 47 | 54 | 124 | 125 | 112 | 55 | 81 | 16 | 24 | 53 | 23 | 35 | 63 | 35 | 31 | 21 | 52 | 5 |

Note: Data in terms of number of individuals taken by 100 sweeps of an insect net.
A: High prairie station (burned); B: Sloping prairie station (burned).

*politus, Deltocephalus albidus, Diabrotica duodecempunctata, Syrbula admirabilis, Epitrix brevis, Lema trilineata, Thyanta custator, Stictocephala lutea,* Melanopthalma* sp.

APPENDIX 4. Characteristic Seasonal Influents of the Norman Lociation.

Vernal Sociation: *Strongylocornus stygicus, Chaetocnema denticulata,*[i] *Ortholomus jamaicensis,*[h] *Mordellistena lutea,*[i] *Stictocephala lutea,*[h,l] *Onychobarus pectorosa,*[i] *Collops quadromaculatus,*[i] *Epitrix brevis.*[s,l]

Estival Sociation: *Peribalis limbolarius, Mormidea lugens,*[l,s] *Œcanthus nigricornis argentatus, Stictocephala lutea,*[i,l] *Sinea diadema.*[s]

Serotinal Sociation: *Idiocerus crataegi,*[i] *Melanoplus bivittatus,*[l,s] *Orphulella pelidna, Mermiria maculipennis, M. neomexicana,*[l,h] *Mecidea longula,*[h] *Syrbula fuscovittata,*[h,l] *S. admirabilis.*

Autumnal Sociation: *Idiocerus crataegi, Cymus virescens, Deltocephalus sandersi.*[i,l]

APPENDIX 5. Presocies of Burned High Prairie Invertebrate Constituents) (see table 5).

Perennial Nucleus:
Incidentals: *Crematogaster lineolata.*

Vernal Socies:
Influents: *Epitrix similis, Melanoplus confusus, Solubea pugnax, Conocephalus pugnax* (nymphs), *Scolops spurcus, Strongylocoris stygicus.*

Incidentals: *Euscelis obscurinervus, Galyssus quinquespinosus, Draeculacephala reticulata, Oncometopia undata, Campylenchia latipes, Chlorotettix unicolor.*

Estival Socies:
Influents: *Diapheromera* sp. *(? veliei), Campylenchia latipes, Conocephalus furcatus, Pediocetes haldmanii, Ortholomus scolopax, Œcanthus nigricornus argentatus, Melanoplus confusus, Amphitornus coloradus, Phlibostroma quadromaculatus.*

Incidentals: *Boopedon* sp., *Campylacantha olivacea, Solubea pugnax, Thamnotettix kennicotti, Galgupha nitiduloides, Macropsis basalis, Bruchomorpha dorsata, Xerophloea viridis.*

Transition to Serotinal Socies:
Influents: *Orpulella pelidna, Syrbula admirabilis, Mermiria maculipennis, Driatura robusta.*

Incidentals: *Vanduzea arquata.*

Serotinal Socies:
Influents: *Ageneotettix deorum, Chlorotettix unicolor, Driotura robusta.*
Incidentals: *Syrbula fuscovittata, Draeculacephala reticulata.*

Autumnal Socies:
Influents: Idiocerus crataegi, Cymus virescens.

Incidentals: *Melanoplus packardii, Strongylocoris stygicus, Campylacantha olivacea, Xerophloea viridis, Homaemus aenifrons, Lygus pratensis.*

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Note: Species indicated by "h" occur in greater numbers on high prairie, "s" on sloping prairie, "i" as incidental species in both, and "l" on low prairies (non-climatic) as well.

TABLE 2. Data for Collections made in Upland Prairie Stations, McClain Co., Okla. Data in terms of number of individu

| Sociation | autumnal | | | | | | | | | | hiemal | | | | | | | | prevernal | | | | vernal | | | | estiv | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1933-35 | Sept. | October | | | | November | | | | Dec. | | Jan. | | | Febr. | | | Mar. | | April | | | | May | | | June | | |
| A | 26 | 5 | 12 | 19 | 28 | 4 | 11 | 18 | 25 | 2 | 17 | 12 | 20 | 28 | 4 | 17 | 24 | 4 | 29 | 7 | 14 | 19 | 27 | 10 | 17 | 25 | 2 | 8 | 17 |
| *Hemiptera* | 2 | 3 | | | | 1 | 2 | 1 | 1 | | | | 2 | | | | | | | | | | | 5 | 2 | 4 | 5 | 2 | 8 |
| *Homoptera* | 34 | 14 | 10 | 12 | 5 | 3 | | 1 | | | | 3 | | 2 | | | | | | 3 | 4 | | 5 | 1 | 5 | | 15 | 3 | 2 |
| *Diptera* ...... | 39 | 3 | 6 | 16 | 4 | 4 | 1 | | 1 | 4 | | | | | | | | | | | 3 | 7 | 8 | 8 | | | 4 | 1 | 1 |
| *Coleoptera* | 3 | 3 | 3 | 3 | | | 2 | | | 1 | | | | | | | | | | 3 | | | | 2 | 12 | 5 | 2 | | 2 |
| *Orthoptera* | 5 | 3 | | | 2 | | | | | | | | | | | | | | | 2 | 2 | 1 | 3 | 3 | 6 | 2 | 27 | 12 | 45 |
| *Spiders* ........ | 18 | 6 | 4 | 3 | | 3 | 11 | 4 | | | | 2 | 1 | 1 | | | 1 | | | 5 | 2 | | 3 | 9 | 8 | | 12 | 5 | 5 |
| *Hymenoptera* | 11 | 2 | | 3 | 1 | | 3 | 1 | | | | | | | | | | | 1 | 3 | 3 | | | 8 | 3 | 3 | 7 | | |
| *Neuroptera* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lepidoptera* | | | | | | | | | | | | | | | | | 1 | | | | | | 2 | 1 | | | 4 | | |
| Miscl. .......... | 3 | 3 | 2 | 3 | 3 | | 2 | | | 2 | | | | | | | | | 1 | | | | | | | | | | |
| Total | 115 | 37 | 25 | 40 | 15 | 11 | 21 | 7 | 2 | 7 | 0 | 5 | 3 | 3 | 0 | 0 | 2 | 0 | 2 | 16 | 14 | 8 | 21 | 37 | 36 | 14 | 76 | 23 | 63 |
| B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hemiptera* | 19 | 40 | 20 | 13 | 3 | 1 | 2 | 1 | 3 | | | | | | | | | | 1 | 1 | 1 | | 2 | 13 | 7 | 4 | 4 | 3 | 2 |
| *Homoptera* | 13 | 8 | 7 | 10 | 3 | 1 | 6 | | 7 | 2 | | | 1 | 6 | | | | | | 2 | 4 | 2 | 12 | 4 | 1 | 4 | 10 | 4 | 8 |
| *Diptera* ........ | 39 | 3 | 4 | 11 | 3 | 7 | 3 | 1 | 9 | 3 | | | 1 | 4 | 2 | 2 | 3 | 1 | 2 | 4 | 1 | 11 | 27 | 3 | 8 | 5 | 4 | | |
| *Coleoptera* | 4 | 3 | 4 | 6 | | | 2 | 1 | | 1 | | | 1 | 1 | | | | | | | 6 | 3 | 17 | 5 | 7 | 7 | 1 | | 10 |
| *Orthoptera* | | 3 | 3 | 2 | | | 2 | | | | 1 | | | | | | | | | | 1 | 1 | | 9 | 4 | 12 | 24 | 22 | 26 |
| *Spiders* ........ | 13 | 3 | 4 | | 4 | 9 | 16 | 3 | 1 | | 1 | | 1 | 3 | | | 1 | 1 | | 4 | 7 | 7 | 3 | 1 | 10 | 11 | 4 | 6 | 10 |
| *Hymenoptera* | 4 | 2 | 4 | | 12 | 1 | 4 | 1 | | 1 | | | | | | | | | 1 | 5 | | 1 | 5 | | 2 | 1 | 4 | 3 | |
| *Neuroptera* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| *Lepidoptera* | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | 1 | | 2 | | 2 | |
| Miscl. .......... | 2 | 3 | 5 | 3 | 2 | 1 | | | | | | | | 2 | | | | | 1 | | | | | | | | | | 2 |
| Total | 94 | 65 | 51 | 45 | 27 | 20 | 35 | 7 | 20 | 7 | 2 | 0 | 4 | 16 | 3 | 2 | 4 | 2 | 5 | 17 | 20 | 25 | 67 | 36 | 39 | 46 | 51 | 40 | 58 |

TABLE 3. Data for Collections made in Low Prairie Station.
Data in terms of number of individuals taken by 100 seweps of an insect net.

| Sociation: | Estival | Ser. | | Autumnal | | | | | | Hiemal | | | | Prevernal | | | | Vernal | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | Aug. | | Sept. | | October | | | Nov. | | Dec. | | Feb. | | Mar. | April | | | May | June |
| 1934-35 | 17 | 6 | 27 | 19 | 30 | 7 | 24 | 31 | 7 | 24 | 9 | 15 | 2 | 12 | 24 | 8 | 13 | 30 | 21 | 4 |
| *Hemiptera* ...... | 7 | | 2 | | | | | 2 | 5 | | | | | 1 | | | | | | 2 |
| *Homoptera* .... | | 2 | 12 | 2 | 8 | 8 | 16 | 6 | 2 | | | | 1 | | 8 | | | | 28 | |
| *Diptera* .......... | 2 | | | | 4 | 6 | 8 | 10 | 5 | 2 | | 1 | 1 | 5 | 46 | | | 1 | 10 | 6 |
| *Coleoptera* ...... | | 6 | | | 5 | 4 | 4 | 2 | 2 | | | 1 | | | 1 | | | 2 | 6 | 3 |
| *Orthoptera* ...... | 37 | 44 | 40 | 14 | 6 | 16 | | | | | | | | | | 1 | | 1 | 1 | 5 |
| *Spiders* .......... | 6 | | 6 | 8 | 10 | 4 | | 2 | 3 | | | | | | 7 | | | 1 | 2 | 1 |
| *Hymenoptera* | | | 2 | | 3 | 2 | 4 | 2 | 1 | | | | | | 1 | | | 3 | 4 | 3 |
| *Lepidoptera* .... | | | 2 | 1 | 2 | 2 | | 2 | | | | | | | 1 | | | | 1 | 3 |
| *Neuroptera* .... | | | 1 | | | | 2 | | | | | | | | 3 | | | | | |
| Miscl. ............... | | | | | | | | | | | | | | | | | | | | 1 |
| Total .......... | 52 | 52 | 65 | 25 | 38 | 42 | 34 | 26 | 18 | 2 | 0 | 2 | 2 | 6 | 67 | 1 | 0 | 8 | 52 | 24 |

ns of number of individuals taken by 100 sweeps of an insect net. A: High Prairie station; B: Sloping prairie station.

| vernal | | | estival | | | | | serotinal | | | | | autumnal | | | | | | | hiemal | | | | | | prevernal | | | vernal | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | | | June | | | | July | | | August | | Sept. | | | Oct. | | | Nov. | | Dec. | | Jan. | Feb. | | March | | April | | May June | | |
| 10 | 17 | 25 | 2 | 8 | 17 | 23 | 7 | 22 | 29 | 6 | 27 | 6 | 19 | 30 | 7 | 24 | 31 | 7 | 24 | 9 | 15 | 12 | 2 | 21 | 12 | 24 | 8 | 13 | 30 | 21 | 4 |
| 5 | 2 | 4 | 5 | 2 | 8 | 10 | 4 | 2 | 3 | 4 | 5 | | 1 | 1 | 5 | 1 | 2 | 4 | | 1 | | | | | | | | | 1 | | |
| 1 | 5 | | 15 | 3 | 2 | 5 | 6 | 7 | | 1 | 3 | 2 | 9 | 14 | 5 | 12 | 11 | 24 | 2 | | | | | | | 2 | 2 | | 1 | | |
| 8 | | | 4 | 1 | 1 | | | | | | | 1 | | 1 | 10 | 5 | 4 | 1 | 3 | 1 | | | | | | 13 | 3 | | 2 | 17 | |
| 2 | 12 | 5 | 2 | | 2 | 2 | 20 | | 6 | 1 | 1 | | 1 | 4 | 3 | 1 | 1 | 1 | 1 | | | | | | | | | | | 7 | |
| 3 | 6 | 2 | 27 | 12 | 45 | 43 | 27 | 26 | 30 | 7 | 23 | 10 | 5 | 5 | 2 | | 2 | | | | | | | | | | | | 1 | 4 | |
| 9 | 8 | | 12 | 5 | 5 | 1 | 3 | 12 | 14 | 5 | 2 | 2 | 2 | 11 | 7 | | 1 | 3 | | | | | | | | 4 | | | | 1 | |
| 8 | 3 | 3 | 7 | | | | | | | 6 | 1 | 3 | 1 | 1 | 8 | 1 | | 2 | | | | | | | | 1 | | | | 9 | 1 |
| | | | | | | | | | | | 2 | | | 1 | | | | | | | | | | | | | | | | | |
| 1 | | | 4 | | | | | | | | 1 | | 1 | 2 | 3 | 4 | 2 | 2 | | | | | | | | 2 | | | 1 | | |
| | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | |
| 37 | 36 | 14 | 76 | 23 | 63 | 61 | 60 | 47 | 53 | 24 | 38 | 19 | 20 | 41 | 43 | 24 | 23 | 37 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 22 | 5 | 0 | 6 | 38 | 1 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 7 | 4 | 4 | 3 | 2 | 22 | 3 | 1 | 5 | 2 | | 2 | 6 | | 4 | 4 | 2 | 7 | 1 | | | | | | | | | | | 3 | |
| 4 | 1 | 4 | 10 | 4 | 8 | 5 | | 3 | 2 | | 13 | 3 | 9 | 8 | | 45 | 5 | 36 | 1 | | | | | | | 2 | 2 | | | 8 | |
| 3 | 8 | 5 | 4 | | | | | | | | | | 1 | 6 | 10 | 8 | 11 | 1 | 6 | | | | | | 1 | 8 | 7 | | 5 | 34 | 11 |
| 5 | 7 | 7 | 1 | | 10 | 4 | 7 | 3 | 8 | | 3 | | | | | 1 | | | | | | | | 1 | | | | | | 9 | 10 |
| 9 | 4 | 12 | 24 | 22 | 26 | 146 | 86 | 56 | 30 | 16 | 29 | 5 | 24 | 11 | 12 | | 2 | 2 | | | | | | | | | 2 | | 4 | 3 | 3 |
| 1 | 10 | 11 | 4 | 6 | 10 | 10 | 3 | 7 | 10 | | 2 | 1 | | 6 | 8 | 2 | | 5 | | | | | | | | | | | | 2 | 4 |
| | 2 | 1 | 4 | 3 | | 1 | | | | | | 1 | | | 6 | 1 | 6 | | | | | | | | | | | | | 1 | 4 |
| | | | | | | | 1 | | | | | 1 | | | | | | | | | | | | | | 2 | | | | | |
| 1 | | 2 | | 2 | | 1 | | 1 | 2 | | 4 | | | 3 | 2 | | | 2 | | | | | | | | 2 | | | | | 1 |
| | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | 39 | 46 | 51 | 40 | 58 | 189 | 100 | 71 | 57 | 18 | 51 | 13 | 34 | 42 | 61 | 32 | 53 | 8 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 14 | 11 | 0 | 9 | 60 | 33 |

| ernal | |
|---|---|
| ay | June |
| 21 | 4 |
| | 2 |
| 28 | |
| 10 | 6 |
| 6 | 3 |
| 1 | 5 |
| 2 | 1 |
| 4 | 3 |
| 1 | 3 |
| | |
| | 1 |
| 2 | 24 |

APPENDIX 6. Presocies of Burned Sloping Prairie (Invertebrate Constituents) (see table 6).

Perennial Nucleus:
Incidentals: *Idiomyrmex pruinosis analis.*

Prevernal Socies:
Influents: *Idiocerus crataegi.*
Incidentals: *Cicadella hieroglyphica.*

Vernal Socies:
Influents: *Pediocetes haldmanii, Conocephalus strictus, Solubea pugnax, Ortholomus scolopax, Deltocephalus configuratus, Thyanta custator, Melanoplus texanus.*
Incidentals: *Sinea diadema, Cymus virescens, Scolopostethus thompsoni, Adelphocoris rapidus, Micrutalis calva, Diapheromera* sp. *(? veliei), Œcanthus nigricornis argentatus, Macropsis basalis, Melanoplus confusa.*

Estival Socies:
Influents: *Solubea pugnax, Conocephalus strictus, Œcanthus nigricornis argentatus, Scolops spurcus, Mecidea longula, Melanoplus bivittatus, Mermiria neomexicana, Orphulella speciosa.*
Incidentals: *Idiocerus crataegi, Sinea diadema, Diapheromera* sp. *(? veliei), Homaemus aenifrons, Xerophloea viridis, Phlepsius truncatus, Driotura robusta, Chlorotettix unicolor, Campylenchia latipes, Euscelis obscurinervis, Boopedon* sp., *Ageneotettix deorum.*

Transition to Serotinal Socies:
Influents: *Syrbula admirabilis, Orphulella pelidna, O. speciosa.*

Serotinal Socies:
Incidentals: *Idiocerus crataegi, Micrutalis calva, Macropsis basalis, Chlorotettix unicolor, Campylenchia latipes, Euscelis obscurinervis, Vanduzea arquata, Melanoplus texanus, Xanthippus corallipes, Mermiria neomexicana, Orphulella speciosa, Syrbula fuscovittata.*

Autumnal Socies:
Influents: *Idiocerus crataegi, Cymus virescens.*
Incidentals: *Ortholomus scolopax, Deltocephalus configuratus, Homaemus aenifrons, Xerophloea viridis, Mecidea longula, Lygus pratensis, Calcoris norvegicus, Helochara communis, Strongylocoris stygicus.*

APPENDIX 7. The Effect of Burning on Burning on Animal Population Composition: High Prairie.

K*: *Strongylocoris stygicus, Solubea pugnax, Chlorotettix unicolor, Œcanthus nigricornis argentatus, Ortholomus scolopax, Cymus virescens, Galgupha nitiduloides, Xerophloea viridis, Oncometopia undata, Vanduzea arquata, Idiocerus crataegi, Syrbula admirabilis, Orphulella pelidna, Mermiria maculipennis, Campylacantha olivacea, Syrbula fuscovittata, Melanoplus bivittatus, Chaetocnema denticulata, Mordellistena lutea, Epitrix brevis, Onychobaris pectorosa, Haltica bimarginata, Hippodamia convergens, Pachybrachys morosus.*

+: *Conocephalus strictus* (nymphs), *Pediodectes haldmanii, Scolops spurcus, Campylenchia latipes, Driotura robusta, Euscelis obscurinervis, Calysus spinosus, Draeculacephala reticulata, Thamnotettix kennicotti, Macropsis basalis, Bruchomorpha dorsata, Homaemus aenifrons, Lygus pratensis, Eritettix similis, Melanoplus confusus, M. packardii, Amphitornus coloradus, Boopedon* sp., *Phlebostroma quad-*

*: K: species present under both conditions; +: species added through the burning of the prairie; —: species lost through burning.

*rimaculata, Ageneotettix deorum, Epicaerus formidulosus, Pachybrachys hepaticus, Dorytomus squamosus, Phalacrus politus, Epitrix brevis, Chalcidoides helixnes.*

—: *Mecidea longula, Peribalis limbolarius, Thyanta custator, Mormidea lugens, Sinea diadema, Stictocephala lutea, Mygodenia serripes, Catonia pumila, Deltocephalus configuratus, D. sandersii, Calcoris norvegicus, Catonia pumila, Mermiria neomexicana, Melanoplus scudderi, Chortophaga viridifasciata, Apion pennsylvanicum, Collops quadromaculata, Colaspis favosa, Bruchus obtectus, Phyllodecta vittilina, Trox* sp.

APPENDIX 8. The Effect of Burning on Animal Population Composition: Sloping Prairie.

K: *Macropsis basalis, Cymus virescens, Scolops spurcus, Œcanthus nigricornis argentatus, Chlorotettix unicolor, Sinea diadema, Idiocerus crataegi, Homaemus aenifrons, Euscelis obscurinervis, Xerophloea viridis, Adelphocoris rapidus, Deltocephalus configuratus, Phlepsius truncatus, Ortholomus scolopax, Thyanta custator, Mecidea longula, Macropsis basalis, Syrbula admirabilis, S. fuscovittata, Melanoplus bivittatus, Mermiria neomexicana, Orphulella pelidna, Phalacrus politus, Epitrix brevis, Epicaerus formidulosus, Chaetocnema denticulata, Mordellistena lutea, Bruchus obtectus, Onychobaris pectorosa, Haltica bimarginata, Collops quadromaculatus, Graphops varians, Pachybrachys morosus.*

+: *Cicadella hieroglyphica, Solubea pugnax, Scolopostethus* sp., *Micrutalus calva, Driotura robusta, Campylenchia latipes, Vanduzea arquata, Lygus pratensis, Calcoris norvegicus, Helochara communis, Melanoplus texanus, M. confusus, Boopedon* sp., *Xanthippus corallipes, Orphulella speciosa, Ageneoetettix deorum, Meloë* sp., *Typhophorus canellus, Hippodamia convergens, Chalcoides helixnes.*

—: *Empoasca radiata, Mormidea lugens, Ortholomus jamaicensis, Strongylocoris stygicus, Peribalus limbolarius, Stictocephala lutea, Euschistus servus, Chariesterus antennator, Graphocephala coccinea, Megalotus quinquespinosus, Catonia pumila, Oncometopia undata, Deltocephalus sandersii, Nabis ferus, Aphodius servus, Dorytomus squamosus, Lepidophorus* sp., *Chalepus nervosus, Anthonomus nigrinus, Epicauta pennsylvanica, Cyliodopterus nanulus, Pachybrachys hepaticus.*

# Mechanically Initiated Bark Growth in Celtis

Cornelius H. Muller

While engaged during the spring of 1938 in making a vegetational survey of the Pere Marquette Wildlife Study Area for the Illinois State Natural History Survey, the author chanced to observe several examples of an odd growth phenomenon. The Pere Marquette Area is located on a point of land in Calhoun County, Illinois, at the juncture of the Illinois and Mississippi Rivers and consists entirely of river-bottom land which is for the most part wooded with typical river-bottom forest.

One common constituent of the forest is *Celtis mississippiensis* Bosc, a species characterized by its very smooth bark on young trunks and its very rough, warty bark on old ones. Associated with *Celtis* in many situations is *Menispermum canadense* L., a twining woody vine which commonly ascends shrubs and young tree trunks in a spiral. In a number of instances young trees of *Celtis* were observed bearing the heavy vines.

Ordinarily the vines persist for five or six or more years before they die and finally fall away. In that interval the supporting plants increase considerably in diameter and greatly tighten the spiral coils of the vines which meanwhile have lignified and markedly increased in tensile strength. The immediate result of this irritation of the tree by the vine is observed as a slight constriction on the bark of the *Celtis* along the spiral line of the vine's position. Trees on which the vines have died and are rotting away may be observed to show such a constriction. Up to this point the host's behavior is identical with that of any other species under the same conditions, but after the trees are freed of the rotting vines, *Celtis* reacts in a manner different from that of other species.

A young trunk of *Celtis* up to about three inches in diameter is usually quite free of warts on its bark. However, if such a tree has recently been freed of a *Menispermum* vine, the old spiral line of constriction will after one or two years be marked by a nearly continuous line of warts or peridermal excrescences. These grow to a protrusion of about half an inch and apparently are identical with the similar tumors which occur here and there all over the trunks of older trees of *Celtis*. There is no doubt that the growth of the tumors is initiated by the presence of the vines on the bark, for their arrangement in definite spirals along old vine positions could hardly be mere coincidence. It might be argued, however, that the inducement of tumor growth is chemical in nature and results from the presence of decomposition products in the rotting vines. Though that is entirely possible, it could not serve as an explanation of the occurrence of isolated tumors here and there on the bark of older trees.

At least one instance of such tumor formation is induced by injury. The activities of certain woodpeckers consist in part of the drilling of small holes in the bark of trees. The author has observed many cases of these birds' work on *Celtis*, and the common reaction of the tree to such injury was the production of a circular tumor surrounding the injury and eventually, as the hole was filled with scar tissue, the production of a wart covering the entire locus of the injury. These warts are identical with those produced on old spiral constrictions of *Menispermum* vines. It is probable, therefore, that in all cases of tumor or wart formation by *Celtis* the growth is initiated by some chance mechanical injury. Local cork formation in other species, such as the normal formation of cork wings on the branchlets of *Ulmus alata* Michx., though probably the result of some similar local stimulus, is apparently caused by an internal rather than an external stimulus.

The growth of the tumors on *Celtis* consists simply of the activity of a secondary meristem (cork cambium) over a small area in the phloem. When this becomes so far removed from the source of food as to cease functioning, another layer of meristem arises beneath it. The result is the production of bark in a manner identical with that in other species except that growth is localized and not in a continuous cylinder covering the entire trunk. This localization of bark formation apparently results from the requirement of mechanical initiation of meristematic activity. Naturally, the mechanical injury which serves to initiate the growth is itself quite local and results in local bark formation.

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# Studies on the Trematode Family Microphallidae, Travassos, 1921, III.

## The genus Maritrema Nicoll, 1907, with description of a new species and a new genus, Maritreminoides.

John S. Rankin, Jr.

### Introduction

A study of the trematode parasites infecting shore birds around Woods Hole, Massachusetts, has revealed a high percentage of infection with worms belonging to the family Microphallidae Travassos, 1921. The genera *Levinseniella* Stiles and Hassall, 1901, and *Cornucopula* n. gen. were considered in the first of this series of papers (1939), and *Spelotrema* Jägerskiold, 1901, in the second (1939a). The present report reviews the status of the genus *Maritrema* Nicoll, 1907, with the description of a new species, *M. ovata,* and proposes *Maritreminoides* n. gen. to contain certain species that exhibit characters incompatible with those of *Maritrema.*

Sincere appreciation is expressed to Dr. C. E. Hadley, Montclair State Teacher's College, and Miss Ruth Castle, Vassar College, for the opportunity of examining living specimens of both immature and adult forms of their new species; to Dr. W. E. Swales, McGill University, for specimens of *M. acadiae;* to Dr. W. C. Gower, Michigan State College, for slides of *M. nettae;* and to Dr. E. W. Price, U. S. Bureau of Animal Industry, Washington, for the privilege of examining museum specimens of species of *Maritrema.*

### Historical Review

The genus *Maritrema* was established by Nicoll (1907) for a group of small trematodes occurring in the intestines of shore birds, with *M. gratiosum* n. sp. as the type species and with descriptions of *M. lepidum* n. sp. and *M. humile* n. sp. Nicoll suggested that perhaps Jägerskiold (1900) had specimens of *M. humile* when he referred to individuals that he could not reconcile with *Levinseniella.* In a later paper (1909), Nicoll erected the subfamily Maritreminae and presented figures for his previously described species. Jägerskiold (1909) described as new, *M. linguilla* and *M. subdolum;* considered the genus *Maritrema* closely related to the genera *Spelotrema* Jägerskiold, 1901, and *Spelophallus* n. gen.; and presented a key to the species of *Maritrema. M. nicolli* was described by Travassos (1921) from Brazil. In a list of trematodes from British birds, Nicoll (1923) apparently suppresses his own subfamily Maritreminae (1909), for he includes *Maritrema* in the subfamily Microphallinae Ward, 1901, in the family Heterophyidae Odhner, 1914. Travassos

(1929) described another new species from Brazil, *M. pulcherrima*. *M. sachalinicum* n. sp. was reported by Schumakowitsch (1932), who included also an extensive key to the valid species.

Swales (1933) described *Streptovitella acadiae* n. gen. et n. sp. from the Black Duck in Nova Scotia, Canada. This genus was shown by Ciurea (1933) to be a synonym of *Maritrema*. The subfamily Maritreminae Nicoll, 1909, is retained by Ciurea to contain the single genus. Mueller (1934), after restudying additional specimens of *Microphallus obstipus* and *M. medius* Van Cleave and Mueller, 1932, concluded that these worms should be transferred to the genus *Maritrema*, primarily because of the presence of a true cirrus sac. Van Cleave and Mueller (1934) reported additional notes on the biology and morphology of *M. obstipum* and *M. medium*. The life-cycle of *M. rhodanicum* n. sp. was studied by Carrière (1936). The morphology and studies on the life-cycle of what is probably a new species of *Maritrema* were reported by Hadley and Castle (1937). The excretory system of the genus was studied by Rothschild (1937, 1938). She records feeding encysted *Cercaria oocysta* Lebour, 1907, to the Black-headed Gull from which she recovered what is apparently a new species of *Maritrema;* a footnote (1937) indicates that a description of this new species will appear elsewhere. Studies on the life-cycle of *M. medium*, with a redescription of the species, were reported by Sheldon (1938). In a study of the parasites of ducks in Michigan, Gower (1938) described *M. nettae* n. sp.

Since the original description of the genus *Maritrema*, various investigators have shown where the generic diagnosis is incomplete, particularly with respect to the excretory system, presence of a seminal vesicle, and the course of the life-cycle. The present study included an intensive examination of living material in which many body details can be distinguished that would be otherwise difficult to observe. The genus *Maritrema*, therefore, is emended and the diagnostic characters of the valid species follow.

### Genus MARITREMA Nicoll, 1907; char. emend.

Diagnosis: *Microphallidae*. Small oval or tongue-shaped trematodes, anterior end of body bluntly tapered, posterior end bluntly rounded; tiny spines cover most of body as far posteriorly as testicular region. Suckers small, approximately of equal size; acetabulum at about body middle. Intestinal crura short, never reaching below anterior level of testes. Ovary at acetabular level, usually somewhat dextral and posterior and overlapping the acetabulum; uterus voluminous, filling space behind ovary, rarely extending in front of the acetabulum. Vitellaria confined to a fringe around the edge of the posterior part of the body; at the anterior level of the testes, the lateral extensions of the fringe turns medially on each side to meet in the mid-body line, so that the vitellaria form almost a complete circle. Seminal receptacle and Laurer's canal present. Testes oval, symmetrical, just behind the ovary; seminal vesicle large, elongate-oval, dextral to and at the anterior edge of the acetabulum, often extending posterior to this sucker; well-developed pear-shaped cirrus

pouch; ductus ejaculatorius empties through a duct in a small papilla into a small genital atrium; prostate gland absent. Genital pore sinistral, at antero-lateral edge of acetabulum. Vagina sinistral, entering genital sinus in rear, near base of male papilla. Excretory bladder V-shaped; flame-cell pattern, 2(2+2)+(2+2). Adult normally in the intestines of shore birds, occasionally in mammals; metacercariae in crustacea. Type species: *M. gratiosum* Nicoll, 1907, from *Calidris alpina*.

Among the outstanding diagnostic characters of this genus are the continuous ring of vitelline follicles that almost completely encircle the posterior part of the body; the uterus limited to and usually filling the posterior body; the approximately equal suckers; and the exit of the male duct limited to a small papilla. Of the many species included in this genus, *M. obstipum, M. medium,* and *M. nettae* exhibit variations that are incompatible with respect to these characters. In these species the vitelline follicles never form a complete ring around the posterior body; the uterus reaches the pharyngeal level with a loop on each side of the body and does not fill the space between the testes and the posterior edge of the body; the acetabulum tends to be almost twice as large as the oral sucker; and the male duct ends in a long protrusible cirrus. These differences are believed significant enough to warrant the removal of these three species from the genus *Maritrema* and a new genus, *Maritreminoides,* is proposed to receive them. The antero-lateral extent of the uterus is a character unique to the family Microphallidae and may form a basis for the elimination of this group from the family. Until further studies are completed, however, it is considered advisable to retain the new genus in the Microphallidae.

1. *Maritrema gratiosum* Nicoll, 1907.

Body measurements. 0.45-1.10 x 0.24-0.44 mm.; suckers nearly equal, 0.04-0.06 mm. in diameter, oral sucker tending to be slightly the larger. Prepharynx, 0.06 mm. long; pharynx, 0.03 x 0.02 mm.; esophagus, 0.06-0.16 mm. long; intestinal crura, 0.16-0.37 mm. long, reaching to anterior edge of testes. Ovary immediately behind acetabulum, median or slightly dextral, somewhat lobate; uterus voluminous, eggs colorless on left side, yellow on right; eggs, 0.020-0.022 x 0.010-0.012 mm. Testes not much overlapped by uterus, elongate-oval, longitudinal axes directed more or less obliquely upwards towards the mid-line. Terminal portion of vagina with a sinuous course. Seminal vesicle extending some distance behind acetabulum; short pars prostatica.

Definitive Hosts: *Calidris alpina, Charadrius hiaticula, Larus ridibundus,* and *Haematopus ostralegus.*

Habitat: Intestine.

Locality: England.

2. *M. lepidum* Nicoll, 1907.

(Original description given as a comparison with *M. gratiosum*). Oral sucker diameter, 0.07 mm.; acetabulum, 0.06 mm., anterior to body middle. Prepharynx short; intestinal crura short, not reaching posterior to acetabulum;

ovary always slightly dextral, somewhat smaller than in *M. gratiosum;* eggs, 0.018-0.019 x 0.009-0.010 mm. Testes further forward, dextral testis almost contiguous with ovary and seminal vesicle; their long axes always transverse and not overlapped by the uterus to any great extent; seminal vesicle much larger, extending as far back as anterior edge of dextral testis. Course of vagina distinctly Z-shaped.

Definitive Hosts: *Larus argentatus, L. ridibundus.*

Habitat: Intestine.

Locality: England.

3. *M. humile* Nicoll, 1907.

Body measurements, 0.28-0.40 x 0.12-0.16 mm. Oral sucker smaller than acetabulum, 0.025-0.031 mm. in diameter; acetabulum, 0.03-0.034 mm. in diameter, nearly in body middle. Prepharynx about same length as pharynx; pharynx, 0.019 x 0.01 mm.; esophagus, 0.04-0.05 mm. long; intestinal crura about twice as long as esophagus, dilated, wide apart, and reach anterior edge of acetabulum. Testes almost entirely enveloped by uterus, symmetrical, transversely oval; seminal vesicle comparatively large; cirrus pouch with exceptionally thick walls, 0.09 x 0.03 mm., and occasionally overlaps acetabulum to considerable extent. Eggs, 0.016-0.018 x 0.008-0.011 mm.

Definitive Host: *Tringa totanus.*

Habitat: Intestine.

Locality: England.

4. *M. linguilla* Jägerskiold, 1909.

Body tongue or biscuit-shaped, 0.45-0.53 x 0.19-0.22 mm.; tiny spines cover most of hind body. Oral sucker, 0.04-0.05 mm. in diameter; acetabulum, 0.0.5 mm. in diameter, somewhat posterior to body middle. Prepharynx about as long as pharynx; pharynx, 0.03 x 0.01 mm.; esophagus (including pharynx and prepharynx), 0.14-0.16 mm. long; intestinal crura short, 0.11 mm., extend to anterior level of acetabulum. Genital opening very wide; small male papilla projects into genital atrium; cirrus pouch well-developed; pars prostatica weakly-developed; testes relatively small, symmetrical, no decided large axis, 0.05-0.06 mm. in diameter. Vagina unusually muscular; uterus very voluminous, large mass of its coils behind testes. Vitelline ducts very thick; ootype, including shell-gland, median, between testes; ovary large, entire, 0.07-0.08 x 0.04 mm., reaching mid-level of acetabulum. Eggs, 0.015-0.016 x 0.008-0.009 mm.

Definitive Host: *Calidris maritima.*

Habitat: Intestine.

Locality: Sweden.

5. *M. subdolum* Jägerskiold, 1909.

Body oval, leaf-like, 0.35-0.50 x 0.21-0.26 mm.; spination to a little behind body middle. Oral sucker somewhat smaller than acetabulum, 0.03-0.04 mm. in diameter; acetabulum, 0.04-0.05 mm in diameter. Pharynx, 0.03 x 0.02 mm.;

esophagus (including pharynx and prepharynx), 0.12-0.15 mm. long; intestinal crura almost to anterior level of testes, 0.12-0.15 mm. long. Testes very large, entire, main axes oblique to body axis, 0.06-0.08 x 0.04-0.05 mm.; ductus ejaculatorius very long, forming a pair of loops inside the cirrus pouch; seminal vesicle not very large. Ovary reaching mid-level of acetabulum, entire, 0.06-0.08 x 0.03-0.04 mm.; uterine coils surround but do not cover testes and fill posterior part of body, with a large loop in front of the testes. Small papilla often projects out of the genital opening. Eggs, 0.019- 0.021 x 0.010-0.011 mm.

Definitive Hosts: *Tringa hypoleucos, Haematopus ostralegus.*

Habitat: Intestine.

Locality: Sweden.

6. *M. nicolli* Travassos, 1921.

Body small, pear-shaped, 0.16-0.24 x 0.19-0.21 mm. Oral sucker, 0.03 mm. in diameter; acetabulum, 0.03 mm. in diameter, at about body middle. Prepharynx, 0.01-0.014 mm. long; pharynx, 0.03 x 0.01 mm.; esophagus, 0.035 mm. long; intestinal crura short, transverse, 0.08 mm. long, wholly anterior to the acetabulum. Genital atrium, 0.012 mm. in diameter; cirrus pouch very large, 0.10 mm. long, almost reaching body edge. Testes entire, 0.03 mm. in diameter. Ovary small, oval, 0.03 x 0.05 mm. Eggs, 0.012 x 0.008 mm.

Definitive Host: *Daphila bahamensis.*

Habitat: Intestine.

Locality: Manguinhos, Rio de Janeiro, Brazil.

7. *M. pulcherrima* Travassos, 1929.

Body thickly-oval, 0.40-0.52 x 0.32-0.38 mm.; cuticular spines 0.0027 mm. long. Oral sucker large, 0.08-0.10 mm. in diameter; acetabulum pre-equatorial, 0.04-0.05 mm. in diameter. Prepharynx very short; pharynx, 0.03-0.04 x 0.02-0.03 mm.; esophagus short, 0.02 mm. long; intestinal crura short, transverse, never reaching to acetabular level, 0.01-0.016 mm. long. Cirrus pouch entirely anterior to acetabulum, 0.12-0.13 x 0.05-0.06 mm. Testes reaching anterior level of acetabulum, lateral, 0.07-0.10 mm. in diameter. Ovary lobate, almost entirely in front of the acetabulum, 0.08-0.10 x 0.06 mm. Vitellaria extend laterally, anterior to and across mid-plane of the acetabulum. Eggs, 0.018-0.020 x 0.010-0.011 mm.

Definitive Host: *Didelphis aurita* Wied.

Habitat: Intestine.

Locality: Angra dos Reis, Rio de Janeiro, Brazil.

8. *M. sachalinicum* Schumakowitsch, 1932.

Body large, pyriform, 0.98-1.20 x 0.43-0.53 mm.; spination to mid-body length. Oral sucker, 0.09 mm., acetabulum, 0.06 mm. in diameter. Prepharynx, 0.04 mm. long; pharynx, 0.04 mm. long; esophagus, 0.21-0.41 mm. long; intestinal crura reach just below anterior level of testes, 0.23-0.41 mm. long. Testes round, symmetrical, 0.08-0.12 x 0.10-0.13 mm.; cirrus pouch and seminal vesicle diagonal and concave, in front of acetabulum. Ovary triangular, lateral and

same plane as acetabulum, 0.10-0.15 mm. in diameter; Mehlis' Gland median, behind ovary and acetabulum. Eggs, 0.02-0.026 x 0.01-0.012 mm.

Definitive Host: *Larus argentatus*.

Habitat: Intestine.

Locality: Sachalin Island, Russia (?).

9. *M. acadiae* (Swales, 1933) Ciurea, 1933.

Syn.: *Streptovitella acadiae* Swales, 1933.

Body tongue-shaped, 0.45-0.62 x 0.15-0.21 mm.; spination to posterior extremity of intestinal crura. Oral sucker, 0.03-0.04 mm. in diameter; prepharynx, 0.05-0.07 mm. long; pharynx, 0.02-0.03 mm. in diameter; esophagus, 0.16-0.18 mm. long, bifurcating at about mid-body length; intestinal crura, 0.19-0.21 mm. long, terminating at anterior level of testes. Testes globular, symmetrical, behind ovary, 0.04-0.06 mm. in diameter; seminal vesicle within a large cirrus pouch, 0.07 mm. long, obliquely transverse, overlapping the anterior half of and extending laterally behind the acetabulum. Ovary globular, 0.04-0.05 mm. in diameter, median, overlapping posterior edge of acetabulum. Receptaculum seminis (first note in literature observing presence of this structure in this genus) globular, 0.03-0.04 mm., median, overlapping posterior edge of ovary; uterus fills free space between posterior level of seminal vesicle and posterior extremity of body. Eggs, 0.019-0.020 x 0.008-0.009 mm., brownish.

Definitive Host: *Anas rubripes*.

Habitat: Small intestine.

Locality: Cole Harbour, Nova Scotiá, Canada.

10. *M. rhodanicum* Carrière, 1936.

Body elongate, 0.63-0.81 x 0.28-0.38 mm. Oral sucker, 0.04-0.06 mm., acetabulum 0.06-0.07 mm. in diameter. Prepharynx, 0.04-0.10 mm. long; pharynx, 0.03-0.04 mm. in diameter; esophagus, 0.10-0.16 mm. long; intestinal crura, 0.21-0.28 mm. long, terminate as far posteriorly as midtesticular level. Testes symmetrical, rounded, 0.11-0.13 mm. in diameter; cirrus pouch near anterior edge of acetabulum, 0.12-0.14 x 0.03-0.04 mm. Ovary spherical, 0.12-0.16 x 0.06-0.07 mm., at posterior dextral edge of acetabulum; uterus fills posterior border and forms two characteristic convolutions around the testes. Eggs, 0.021-0.022 x 0.011 mm.

Definitive Host: *Larus argentatus michahellesii* Bruch.

Habitat: Intestine.

First Intermediate Hosts: *Paludestrina acuta* (Drap.), *Pseudammonicola similis* (Drap.).

Second Intermediate Hosts: *Gammarus locusta* Linn., *G. pulex* Linn.

Locality: France.

11. *Maritrema* sp. Hadley and Castle, 1937.

Body, 0.86 x 0.38 mm. Suckers approximately equal; prepharynx and pharynx each 0.03 mm. in length; esophagus, 0.15 mm.; intestinal crura extend to anterior level of testes, 0.24 mm. long. Testes lateral, 0.09 x 0.11 mm.;

ovary just posterior and dextral to the acetabulum, 0.07 x 0.15 mm.; eggs, 0.010 x 0.020 mm. Well-developed seminal vesicle and cirrus pouch immediately anterior to acetabulum.

Definitive Host: *Arenaria interpres morinella* (Linn.)
Habitat: Intestine.
Second Intermediate Host: *Balanus balanoides* Linn.
Locality: Woods Hole, Massachusetts, U. S. A.

12. **M. ovata** sp. nov. (Fig. 1-3).

Body small and ovate (whence specific name), though often extending twice resting length, 0.40-0.52 x 0.19-0.30 mm.; tiny spines cover body surface to below testicular level (Fig. 1). Oral sucker, 0.03-0.04 x 0.03-0.05 mm.; acetabulum just anterior to body middle, 0.03-0.05 x 0.03-0.07 mm.; both suckers with two rows of tiny spines. Prepharynx short, often practically invisible, 0.02-0.03 mm. long; pharynx bulbous, 0.02-0.03 x 0.01-0.02 mm.; esophagus fairly short, 0.05-0.09 mm., bifurcates at anterior limit of second body third, well anterior to the acetabulum into two wide intestinal crura that extend below the acetabulum to the testicular level, 0.11-0.18 mm. long. Ovary elongate-oval, 0.03-0.08 x 0.07-0.11 mm., median or somewhat dextral, usually almost entirely posterior to the acetabulum or just overlapping the posterior edge of this sucker; short oviduct leaves the left anterior edge of the ovary, receives immediately the duct from the Receptaculum seminis followed by the common vitelline duct, and then proceeds posteriorly between the two testes; uterus voluminous, filling space behind and between the testes, with a couple of coils lateral to the testes extending to and often overlapping the intestinal crural tips; uterus makes a few characteristic folds between the acetabulum and the left intestinal fork, and then enters the genital sinus from the dorsal side near the base of the male genital papilla (Fig. 2). Receptaculum seminis large and bulbous, in mid-body line, immediately posterior to the ovary and contiguous with the yolk-reservoir; Laurer's Canal present. Vitellaria extensively developed, consisting of numerous small follicles forming a fringe around the entire posterior part of the body; follicles often overlapping tips of the intestinal crura and may on the left side, extend somewhat anterior and lateral to the acetabulum; the right vitelline path crosses the middle of the ovary to join its fellow just to the left of the mid-line immediately anterior to the testes; large, pear-shaped yolk-reservoir located to left of and contiguous with the Recetaculum seminis. Eggs, 0.019-0.024 x 0.008-0.011 mm., bright yellow.

Testes spherical, large, in posterior body third, immediately behind the ovary; right testis, 0.06-0.10 x 0.08-0.12 mm.; left testis, 0.06 x 0.10 mm.; large elongate-oval cirrus pouch, 0.09-0.11 mm. long, dextral, usually extending posterior to the acetabulum to the testicular level, often lying transversely in front of the acetabulum; short coiled ductus ejaculatorius empties by a large male papilla into the small genital atrium (Fig. 2). Excretory bladder V-shaped (Fig. 3); flame-cell system, 2 (2+2) + (2+2).

Definitive Hosts: *Charadrius semipalmatus* Bonaparte, *Crocethia alba* (Pallas), *Limnodromus griseus* (Gmelin).

Habitat: Intestine.

Locality: Sippiwissett Beach, West Falmouth, Massachusetts, U. S. A.

Type and cotypes have been deposited in the U. S. National Museum, Washington, D. C., U. S. N. M. no. 9251.

*Maritrema ovata* n. sp. was collected from Sippiwissett Beach only, birds from other nearby localities being free from infestation with this worm. One out of the 5 Sanderlings *(C. alba)* collected harbored 200 parasites; one Dowitcher *(L. griseus)*, 150; and 2 Ring-necked Plovers *(C. semipalmatus)*, an average of 30 per host.

*M. ovata* may be distinguished easily from *M. lepidum, M. humile, M. linguilla, M. nicolli,* and *M. pulcherrimum,* in the greater extent of the intestinal crura; in *M. ovata* the crura extend to the anterior level of the testes, while in these outer species the crura terminate either wholly in front of or just at the anterior edge of the acetabulum. *M. ovata* differs from *M. gratiosum* by the larger, non-lobate ovary, spherical testes, and shorter, more squat, body outline; from *M. subdolum,* by the comparatively straight ductus ejaculatorius within the cirrus pouch, spherical testes, and larger intestinal crura; from *M. sachalinicum,* by the much smaller size, greater posterior extent of the cirrus pouch, and ovate ovary; from *M. acadiae,* by the elongate-oval Receptaculum seminis located posterior to the ovary and not overlapping that organ, greater development of the vitellaria, and the much shorter esophagus; from *M. rhodanicum,* by the smaller body size, more nearly equal size of the suckers, further posterior termination of the cirrus pouch, and shorter esophagus; and finally, from Hadley and Castle's new *Maritrema* sp., by its smaller body size, much shorter esophagus, and further posterior termination of the cirrus pouch.

A review of the literature, therefore, indicates that there are now twelve described species of *Maritrema,* and two species indicated as new, the descriptions and names of which have not yet appeared (Rothschild, 1937; Hadley and Castle, 1937). A careful study of the figures and descriptions of many of these species indicates that the specific diagnoses are either inadequate, or that synonymy should result, for it is extremely difficult to separate one from the other in many instances. Until further information, can be obtained, however, it is considered advisable to retain the specific status of the different forms described.

Few notes occur as to the course of the life-cycle of species of the genus *Maritrema.* Adults are found normally in the intestines of shore birds. Only one species *(M. pulcherrima)* has been reported from a mammal *(Didelphis aurita.).* This is probably a case of accidental parasitism. Along with the description of the genus, Nicoll (1907) suggested that the xiphidiocercaria, *C. oocysta* Lebour, 1907, might be the larval stage of a *Maritrema* sp. Lebour (1911) agreed with Nicoll. Sinitzin (1911) expressed the opinion that two related species of cercariae with which he was working probably developed into adults of the subfamily Microphallinae. This was proven experimentally by Rothschild (1937) who fed encysted *C. oocysta* to the Black-headed Gull and recovered what is apparently a new species of *Maritrema.* Carrière (1936)

found xiphidiocercariae developing in sporocysts in *Paludestrina acuta* and *Pseudammonicola similis* that penetrated and encysted in the crustacea, *Gammarus locusta* and *G. pulex,* and which developed in birds into *Maritrema rhodanicum* n. sp. Metacercariae were recovered from the barnacle *(Balanus balanoides)* by Hadley and Castle (1937) which are undoubtedly young stages of a *Maritrema* sp. occurring in the Ruddy Turnstone *(Arenaria i. morinella).* McMullen (1937), basing his conclusions on the presence of a xiphidiocercaria in the life-cycle of *Maritrema* species, suggests that the natural position of the genus would be in the superfamily Plagiorchioidea Dollfus, 1930; emend. McMullen, 1937, perhaps in the family Lecithodendriidae Odhner, 1910. As will be discussed in a later paper, the writer agrees with McMullen except that the genus will be retained in the family Microphallidae Travassos, 1921.

From this account, it is evident that the course of the life-cycle is as follows: miracidia penetrate molluscs, develop into sporocysts which produce xiphidiocercariae that penetrate various species of crustacea, and reach maturity in the intestines of various avian hosts, primarily shore birds.

### **Maritreminoides** gen. nov.

Diagnosis: *Microphallidae.* Small oval trematodes; skin completely covered with tiny spines. Acetabulum usually much larger than oral sucker, located somewhat anterior to body middle. Prepharynx, pharynx, and esophagus always present; prepharynx and esophagus short; intestinal crura short, never reaching below the anterior level of the acetabulum, usually entirely in front of it. Ovary on same plane as acetabulum, somewhat dextral and posterior, but always overlapping this sucker. Main mass of uterus immediately posterior to acetabulum with a few coils surrounding the testes and a lateral loop on each side extending anteriorly to the level of the pharynx. Vitellaria usually confined to area immediately anterior and lateral to the testes, with a few follicles extending posterior to the testes, never reaching the posterior end of the body or uniting anteriorly or posteriorly. Testes spherical, symmetrical, located about half the distance between the acetabulum and the posterior end, not contiguous with the ovary. Large arcuate cirrus pouch, anterior to acetabulum, may extend dextrally as far down as the posterior level of the acetabulum and reaches to or beyond the lateral extensions of the intestinal crura on each side; proximal end with tubular seminal vesicle, distal end with prostate cells; ductus ejaculatorius prolonged into a long, protrusible cirrus. Genital pore sinistral to and at the median level of the acetabulum. Vaginal opening close to male opening in small genital sinus. Excretory bladder V-shaped, often appearing Y-shaped when contracted. Adult in water birds and possibly fishes.

Type species: *Maritreminoides nettae* (Gower, 1938).

*M. nettae* is used as the type because it was the first species to be described from mature specimens from natural infections. Although no seminal receptacle or Laurer's canal are reported for species of this genus, further studies will probably show their presence, for these structures have been found in other genera of the Microphallidae. The genus *Maritreminoides* differs from all

other genera in the family by the antero-lateral uterine coils and the long protrusible cirrus. It appears to be more closely related to the genus *Maritrema* than to the others, but differs from *Maritrema* by the non-circular arrangement of the vitellaria, the large acetabulum, the more posterior testes, and the more anterior massing of the uterine coils.

## SPECIES OF MARITREMINOIDES

1. *Maritreminoides nettae* (Gower, 1938).

Syn.: *Maritrema nettae* Gower, 1938.

Body small, posterior end often sharply truncate, 0.40-0.45 x 0.24-0.29 mm. Oral sucker, 0.04-0.05 mm. in diameter; prepharynx, 0.01-0.03 mm. long; pharynx, 0.03-0.04 mm. in diameter; esophagus, 0.01-0.03 mm. long; intestinal crura large and thick-walled, reach nearly to edge of body, terminate at anterior acetabular level, 0.10-0.12 mm. long. Acetabulum, 0.06-0.07 mm. in diameter, just anterior to body middle, about twice size of oral sucker. Testes about equal, 0.04-0.07 mm. in diameter. Cirrus pouch large, cresent-shaped, extending almost across the entire body in front of the acetabulum; cirrus very long, protrusible and spined. Ovary oval, 0.04-0.05 x 0.06-0.07 mm. Eggs large, yellowish brown, 0.009-0.012 x 0.019-0.022 mm. Vitellaria consist of small follicles, limited largely to the anterior level of the testes with a few follicles extending a short ways posterior to the testes.

Definitive Hosts: *Glaucionetta clangula americana, Nyroca affinis.*

Habitat: Intestine.

Locality: Michigan, U. S. A.

2. *M. obstipum* (Van Cleave and Mueller, 1932).

Syn.: *Microphallus obstipus* Van Cleave and Mueller, 1932.
*Maritrema obstipum* (Van Cleave and Mueller) Mueller, 1934.

Body ovoid, 0.48 x 0.28 mm. Acetabulum median, 0.06 mm. in diameter, about equal to oral sucker. Pharynx, 0.05 mm. long; prepharynx and esophagus about equal to pharynx in length; intestinal crura large, anterior to acetabulum. Testes immediately posterior to the acetabulum. Ovary spherical, almost within, but slightly dextral to the acetabular confines. Vitellaria composed of small number of follicles, largely at anterior level of testes, with a few follicles distributed along the lateral margins of the body almost to the posterior end. Cirrus short; cirrus pouch elongated and tubular, extending transversely anterior to the acetabulum from one crural tip to the other.

Definitive Host: *Ambloplites rupestris.*

Habitat: Intestine.

Locality: Oneida Lake, New York, U. S. A.

3. *M. medium* (Van Cleave and Mueller, 1932).

Syn.: *Microphallus medius* Van Cleave and Mueller, 1932.
*Maritrema medium* (Van Cleave and Mueller) Mueller, 1934.
*Maritrema medium*. Sheldon, 1938.

Body ovoid, posterior end truncate, anterior end bluntly rounded, 0.60-0.51

x 0.40-0.33 mm. Oral sucker about half the size of the acetabulum, 0.03-0.05 mm. in diameter; acetabulum, 0.07 mm. in diameter. Prepharynx very short; pharynx short, 0.02 x 0.03 mm.; esophagus, 0.10 mm. long; intestinal crura short, 0.10 mm. long, terminate some distance anterior to the acetabulum. Testes spherical, in posterior body fourth. Ovary spherical, overlapping and usually largely posterior to the acetabulum. Vitellaria limited to a transverse band immediately anterior to the testes, not uniting in the mid-body line. Long arcuate cirrus pouch in front of the acetabulum; proximal end may extend to posterior level of acetabulum; distal end with a small loop. Eggs, 0.020 x 0.010 mm.

Definitive Hosts: *Perca flavescens, Ambloplites rupestris.*

Habitat: Intestine.

Experimental Host: Laboratory mouse.

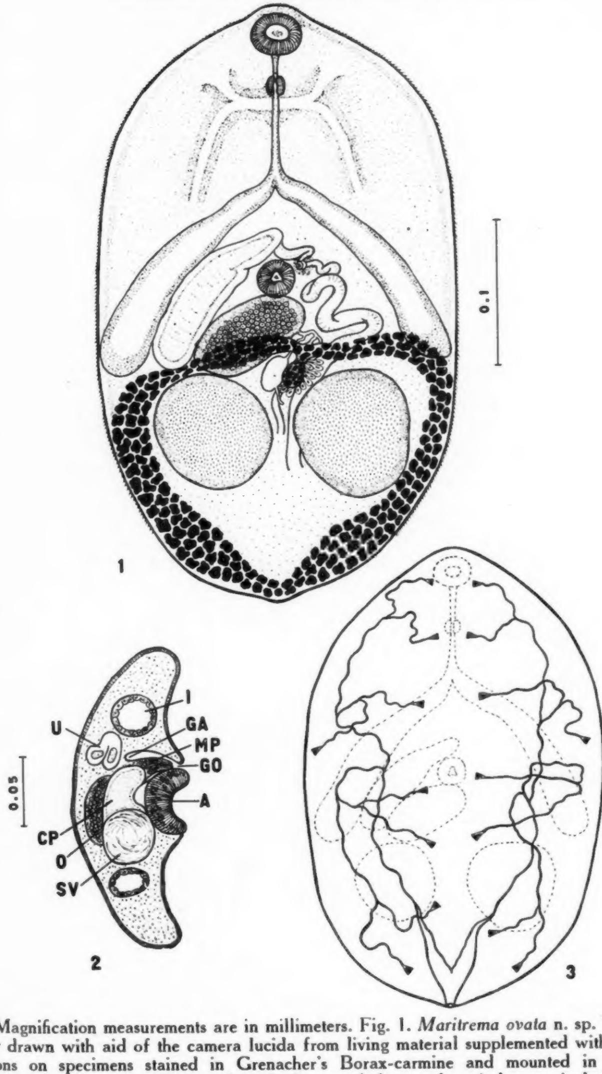
Second Intermediate Hosts: Metacercariae on gills of *Cambarus virilis* and *C. propinquus.*

Locality: Oneida Lake, New York; lakes around Douglas Lake, Michigan, U. S. A.

A few notes occur with respect to the life-cycle and distribution of members of this genus. Since only immature forms and worms still within the metacercarial cyst were recovered, Van Cleave and Mueller (1934) suggested that fishes were probably accidental hosts; they observed also, that the metacercariae might be found in crayfishes or in some small aquatic animal which is eaten by the definitive hosts, probably a fish-eating bird or mammal. Sheldon (1938) fed cysts of *M. medium* found in crayfishes to laboratory mice and recovered adult worms. No experimental host, however, was found in which the worms would mature in large numbers. Although Sheldon fed cysts to tadpoles, perch, catfishes, mice, man, a tern, a herring gull, and canaries, mature worms were recovered from mice only. Fishes, apparently, may serve as transfer hosts since excysted worms were obtained. In a study of the seasonal abundance of parasites in wild ducks, Gower (1938a) found a high incidence of infection with *M. nettae* during winter, and suggests that this may be correlated with the feeding habit of the definitive host, assuming the second intermediate host of the parasite to be a crayfish. Ducks, during heavy winters, feed in running streams where these crustaceans may be obtained.

## Summary

The trematode genus *Maritrema* Nicoll, 1907, is reviewed and emended. The diagnostic characters of the different species are included as is the description of a new species, *M. ovata,* from *Charadrius semipalmatus, Crocethia alba,* and *Limnodromus griseus* collected near Woods Hole, Mass. *M. obstipum, M. medium,* and *M. nettae* are transferred to a new genus, *Maritreminoides,* because of characters incompatible with those of *Maritrema. Maritreminoides* is differentiated from all other genera in the Microphallidae by the lateral extent of the uterus to the level of the pharynx and the presence of a long, protrusible cirrus.




Magnification measurements are in millimeters. Fig. 1. *Maritrema ovata* n. sp. Ventral view drawn with aid of the camera lucida from living material supplemented with observations on specimens stained in Grenacher's Borax-carmine and mounted in damar. Fig. 2. *M. ovata*. Cross-section through the acetabulum and genital pore, including the male papilla, drawn with aid of the camera ludica: A, acetabulum; CP, cirrus pouch; GA, genital atrium at entrance of vagina; GO, genital opening; I, intestine; MP, male papilla; O, ovary; SV, seminal vesicle; U, uterus. Fig. 3. *M. ovata*. Excretory system, sketch drawn from living material.

## REFERENCES

CARRIÈRE, P. 1936—Sur le cycle évolutif d'un Maritrema. Compt. Rend. Acad. Sci., Paris, **202**:244-246.

CIUREA, I. 1933—Les vers parasitaires de l'homme, des mammiferes et des oiseaux provenant des poissons du Danube et de la Mer Noir. Premier mémoire. Trematodes, famille Heterophyidae Odhner, avec un essai de classification des trematodes de la superfamille. Arch. roumain. Path. Exper. Microbiol. **6**:1-134.

GOWER, W. C. 1938—Studies of the trematode parasites of ducks in Michigan with special reference to the Mallard. Mem. Mich. State Coll. Agric. Exper. Sta. **3**:1-94.

———1938a—Seasonal abundance of some parasites of wild ducks. Jour. Wild Life Manage. **2**:223-232.

HADLEY, C. E. AND R. M. CASTLE. 1937—A trematode of genus *Maritrema* (Nicoll) parasitic in the barnacle and Ruddy Turnstone. Abst. in Anat. Rec. **70**, Supplement 1:139.

JÄGERSKIOLD, L. A. 1900—*Levinsenia (Distomum) pygmaea* (Levinsen), ein genitalnapftragendes Distomum. Centralbl. Bakt. 1, **27**:732-740.

———1909—Kleine Beiträge zur Kenntniss der Vogeltrematoden. Centralbl. Bakt., Orig., **48**:302-307.

LEBOUR, M. V. 1911—A review of the British marine cercariae. Parasitology **4**: 416-456.

MCMULLEN, D. B. 1937—A discussion of the taxonomy of the family Plagiorchiidae Luhe, 1901, and related trematodes. Jour. Parasitol. **23**:244-258.

MUELLER, J. F. 1934—Note on *Microphallus obstipus* and *M. medius* Van Cleave and Mueller. Proc. Helminth. Soc. Wash. **1**:5.

NICOLL, W. 1907—Observations on the trematode parasites of British birds. Ann. Nat. Hist., Ser. 7, **20**:245-271.

———1909—Studies on the structure and classification of the digenetic trematodes. Quart. Jour. Micro. Sci., n. s., **53**:391-487.

———1923—A reference list of the trematode parasites of British birds. Parasitology **15**:151-202.

RANKIN, J. S., JR. 1939—Studies on the trematode family Microphallidae Travassos, 1921. I. The genus *Levinseniella* Stiles and Hassall, 1901, and description of a new genus, *Cornucopula* n. gen. Trans. Amer. Micr. Soc., *in press*.

———1939a—Studies on the trematode family Microphallidae Travassos, 1921. II. The genus *Spelotrema* Jägerskiold, 1901, and description of a new species, *S. papillorobusta*. *Ibid.*, *in press*.

ROTHSCHILD, M. 1937—Note on the excretory system of the trematode genus *Maritrema* Nicoll, 1907, and the systematic position of the Microphallinae Ward, 1901. Ann. Mag. Nat Hist., Ser. 10, **19**:355-365.

———1938—A further note on the excretory system of *Maritrema* Nicoll, 1907 (Trematoda). Ann. Mag. Nat. Hist., Ser. 11, **1**:157-158.

SCHUMAKOWITSCH, E. E. 1932—Eine neue Trematode *Maritrema rhodanicum* n. sp. aus einer Möwe *(Larus argentatus)*. Zool. Anz. **98**:134.

SHELDON, A. J. 1938—Studies on the life cycle of *Maritrema medium* (Trematoda) and a redescription of the species. Jour. Parasitol. **24**:259-262.

SINITZIN, D. T. 1911—Parthenogenetic generation of trematodes and its progeny in the molluscs of the Black Sea. Mém. Acad. Sci. St. Petersb., 8, **30**:1-127.

SWALES, W. E. 1933—On *Streptovitella acadiae* (gen. et spec. nov.). A trematode of the family Heterophyidae from the black duck *(Anas rubripes)*. Jour. Helminth. **11**:115-118.

TRAVASSOS, L. 1921—Contribuição para o conhecimento da fauna helmintologica brazileira IX. Sobre as especias da subfamilia Microfalinae Ward, 1901. Arch. Escol. Sup. Agri. Med. Vet., Nictheroy, 4 (1920), **1921**:85-91.

———1929—Alguns trematodeos da familia Heterophyidae observados no Brasil. Ann. da Acad. Brasileira de Sci., **1**(1):14.

VAN CLEAVE, H. J. AND J. F. MUELLER. 1932—Parasites of Oneida Lake fishes. Part 1. Descriptions of new genera and new species. Roosev. Wild Life Annals **3**:1-72.

———1934—Parasites of Oneida Lake fishes. Part 3. A biological and ecological survey of the worm parasites. Roosev. Wild Life Annals **3**:161-334.

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# Additional Notes on the Naiades (Fresh-Water Mussels) of the Lower Tennessee River

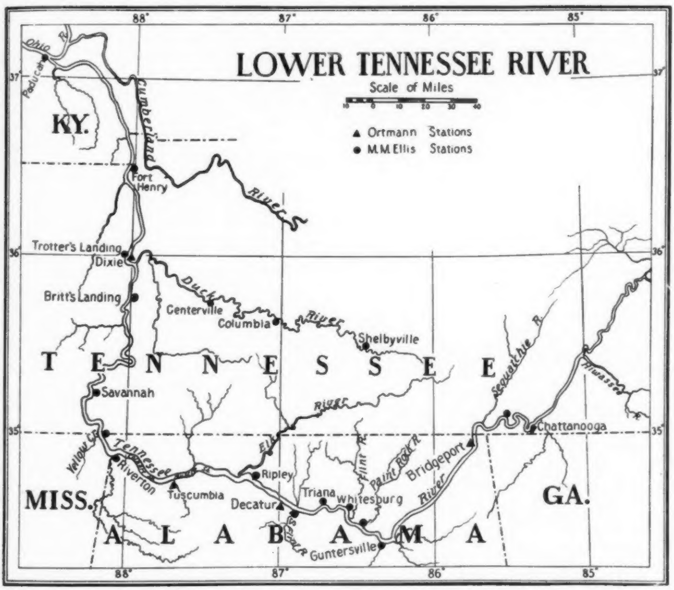
Henry van der Schalie

In 1925, Dr. A. E. Ortmann published in this journal the results of his investigations of the fresh-water mussels in the Tennessee drainage below Walden Gorge. That study constitutes the only source of basic information available for this group of animals in the entire lower Tennessee River. Recently, considerable additional material regarding the mussels inhabiting the main portion of the river from Walden Gorge to its mouth at Paducah has been made available for study. The collections upon which this research is based were largely accumulated by Dr. M. M. Ellis of the U. S. Bureau of Fisheries, who with the aid of a staff of field assistants surveyed the lower Tennessee in July and August of 1931. The information resulting from this survey has been supplemented by records available in the collections of the University of Michigan Museum of Zoology, and by reference to citations in the literature.

The Tennessee Valley Authority undoubtedly will alter completely the ecological conditions for the naiads inhabiting the lower Tennessee River. If, after the impounding of waters, the reaction of the mussels now occupying that region is similar to that of mussels found in ponded areas elsewhere, we can predict safely that the proposed Gilbertsville Dam at Paducah will entirely change the fauna now found in the lower Tennessee. Records which give definite information as to the ecology and distribution of the naiads of this area prior to the construction of such power dams will consequently be valuable for future studies of the taxonomy and zoögeography of these animals. The accumulation of such information becomes increasingly important when we consider that Ortmann (1925) established only four stations in a zone covering approximately 450 miles of the main stream below Walden Gorge (see map). Fortunately, the collections made by Dr. Ellis and his staff have added fifteen stations, so that there is now available considerably more detailed information about the mussels inhabiting the lower Tennessee River. Certain major conclusions regarding the zoogeography of the naiads in the lower Tennessee have already been presented by Ortmann (1925). The data of this paper serve merely as a supplement to the fundamental ideas already expressed by him.

The mussels listed in Table 1 as present in the lower Tennessee below Mussel Shoals agree remarkably with the list of species given by Ortmann (1925. 368) for Dixie, Tennessee. Only two species, *Ptychobranchus fasciolaris* and *Lampsilis ovata ventricosa,* are not verified for the main stream in the lower Tennessee. However, the more detailed data presented here do not

substantiate Ortmann's suggestion that an additional twenty-six species might be added later to those he reported, thus bringing the number of naiad species in the lower Tennessee to fifty-one. It is undoubtedly true that the portion of this stream which contains the Interior Basin fauna potentially may contain fifty-one species, but all available records from the main portion of the river in this area strongly indicate that the fauna actually consists of about twenty-five species and not twice that number. This situation suggests similar observations in studies of other drainages, in that although the potential number of species may be large, the number actually inhabiting an area is restricted by ecological conditions. The *large-river* habitats found in the lower Tennessee consequently restrict the potential fifty-one species to about half that number,




that is, to those which find a large-river environment suitable to their existence.

Another striking example of the role ecology plays in distribution is clearly illustrated by contrasting the restricted number of species present under the large-river conditions of the lower Tennessee River with the unusually large number of species (Ortmann, 1925: 366-67) which inhabit the region of Muscle Shoals. These shoals demonstrate the effect of a rejuvenation of a portion of a stream upon its naiad fauna. This rejuvenescence is reflected in the presence of many species that commonly inhabit creeks and small rivers, in addition to species common to a large-river habitat. Such species as *Fusconaia cuneolus, F. barnesiana, Quadrula intermedia, Lexingtonia dolabelloides,*

TABLE 1.

DISTRIBUTION OF MUSSELS IN MAIN STREAM OF TENNESSEE RIVER AS INDICATED BY RECENT COLLECTIONS.

| | Paducah, Kentucky | Fort Henry, Tenn. | Trotter's Landing, Tenn. | Dixie, Tennessee | Britt's Landing, Tenn. | Savannah, Tennessee | at Yellow Creek, Ala. | Muscle Shoals, Alabama | Ripley, Alabama | Decatur, Alabama | at Flint River, Ala. | Triana, Alabama | 11 mi. s. of Huntsville, Ala. | Paint Rock, Alabama | Guntersville, Alabama | Bridgeport, Alabama | below Chattanooga, Tenn. | at Hiwasee River, Tenn. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cumberlandia monodonta* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | .. | .. | C | .. | .. | .. | .. | .. |
| *Fusconaia ebenus* | 39 | 2 | .. | D | .. | 10 | .. | M | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Fusconaia undata* | 4 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Fusconaia subrotunda* | 1 | .. | G | D | .. | .. | .. | M | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Megalonaias gigantea* | 15 | 7 | G | D | 22 | 9 | .. | M | .. | .. | 9 | .. | .. | .. | .. | .. | .. | .. |
| *Amblema costata* | 2 | .. | G | D | .. | .. | .. | M | .. | 3 | 12 | .. | C | .. | 2 | .. | .. | .. |
| *Quadrula cylindrica* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | A | .. | .. |
| *Quadrula pustulosa* | 7 | 2 | G | D | 4 | 26 | 1 | M | .. | .. | 19 | .. | .. | .. | 6 | A | .. | 2 |
| *Quadrula nodulata* | 10 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Quadrula quadrula* | 16 | 2 | G | D | .. | .. | .. | M | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Quadrula metanevra* | 14 | 1 | .. | D | 1 | 28 | .. | M | 2 | 1 | 13 | 5 | C | .. | 12 | A | .. | 2 |
| *Tritigonia verrucosa* | .. | .. | .. | D | .. | .. | .. | M | .. | .. | 2 | .. | C | .. | G | A | .. | .. |
| *Cycl. tub. granifera* | 5 | .. | G | D | .. | 16 | .. | M | .. | .. | 10 | .. | .. | .. | 2 | A | .. | .. |
| *Plethobasus cooperianus* | 2 | .. | .. | D | .. | 16 | .. | .. | .. | .. | .. | .. | .. | .. | .. | A | .. | 1 |
| *Lexingtonia dolabelloides* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | A | .. | .. |
| *Lex. dol. conradi* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| *Ptychobranchus fasciolare* | .. | .. | .. | D | .. | .. | .. | M | .. | .. | .. | .. | .. | .. | .. | A | .. | .. |
| *Pleurobema cordatum* | 24 | .. | G | D | 3 | 84 | .. | M | 7 | 1 | 170 | 1 | C | .. | 32 | A | .. | 3 |
| *Pleur. cord. coccineum* | .. | .. | .. | .. | .. | 5 | .. | M | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Pleur. cord. plenum* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | .. | .. | C | .. | .. | A | .. | .. |
| *Pleur. cord. pyramidatum* | 7 | 3 | .. | D | 2 | 8 | .. | M | 1 | 1 | 11 | 3 | .. | .. | 2 | A | .. | 1 |
| *Elliptio crassidens* | 4 | .. | G | D | 1 | 14 | .. | M | .. | .. | 12 | .. | C | .. | 6 | A | .. | 9 |
| *Elliptio dilatatus* | 1 | .. | .. | D | .. | 1 | .. | M | .. | 1 | 11 | .. | C | .. | 2 | A | .. | .. |
| *Anodonta imbecillis* | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Strophitus rugosus* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| *Obliquaria reflexa* | 7 | 6 | .. | D | 3 | 7 | .. | M | .. | .. | 6 | 2 | C | 1 | .. | A | .. | .. |
| *Dromus dromas* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | A | .. | .. |
| *Cyprogenia irrorata* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | A | .. | .. |
| *Obovaria retusa* | .. | .. | G | D | .. | 1 | .. | M | .. | .. | 3 | .. | .. | .. | .. | A | .. | .. |
| *Obovaria olivaria* | 3 | .. | .. | D | .. | 11 | .. | M | .. | .. | 1 | 1 | .. | .. | 1 | A | .. | .. |
| *Actinonaias car. gibba* | .. | .. | G | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | A | .. | .. |
| *Plagiola lineolata* | .. | .. | .. | D | 2 | .. | .. | M | .. | .. | 2 | .. | .. | .. | .. | A | .. | .. |
| *Proptera alata* | .. | .. | G | D | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | 1 | .. | .. | 2 |
| *Leptodea fragilis* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | .. | .. | .. | .. | .. | A | .. | .. |
| *Carunculina parva* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. |
| *Ligumia recta latissima* | .. | .. | G | D | .. | .. | .. | M | 1 | .. | 4 | .. | .. | .. | .. | A | .. | .. |
| *Lampsilis anodontoides* | 1 | .. | .. | D | .. | .. | .. | M | .. | .. | .. | .. | C | .. | .. | .. | .. | .. |
| *Lampsilis ovata* | .. | .. | .. | D | .. | .. | .. | M | .. | .. | 1 | .. | C | .. | .. | A | .. | .. |
| *Lampsilis fasciola* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | .. | .. | .. | .. | .. | A | .. | .. |
| *Lampsilis orbiculata* | .. | 1 | .. | D | .. | .. | .. | M | .. | .. | 1 | .. | C | .. | .. | .. | .. | .. |
| *Truncilla truncata* | 4 | .. | .. | .. | 6 | 1 | .. | M | .. | .. | 9 | .. | .. | .. | .. | .. | .. | .. |
| *Truncilla donaciformis* | 1 | 1 | .. | .. | .. | 1 | .. | M | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| *Dysnomia triquetra* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | A | .. | .. |
| *Dysnomia torulosa* | .. | .. | .. | .. | .. | .. | .. | M | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| *Plethobasus cyphyus* | .. | .. | .. | D | .. | 1 | .. | M | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |

Figures in the above table give the number of specimens represented in the M. M. Ellis collection.

The letters used represent collections made by the following: A—C. C. Adams; C—Wm. J. Clench; D—A. E. Ortmann; G—Calvin Goodrich; M—Muscle Shoals Records.

*Lasmigona costata, Strophitus rugosus, Ptychobranchus fasciolaris, P. subtentum, Actinonaias pectorosa, Conradilla caelata, Medionidus conradicus, Micromya fabalis, M. nebulosa, M. taeniata, Lampsilis fasciola,* and several species of *Dysnomia,* are generally confined to headwaters and tributaries of the Tennessee drainage. The wide range of ecological conditions afforded by the intrusion of shoals in this portion of the lower Tennessee has resulted in the maintenance at Muscle Shoals of the largest number of species found anywhere. Ortmann (1924) stated: "There is no other place upon the whole wide world which could be compared with this one in this respect."

The distributional data (Table 1) clearly substantiate Ortmann's contention (1924, 566) that at Muscle Shoals "two old faunas come together, the so-called 'Cumberlandian,' belonging to the upper Cumberland and the upper Tennessee rivers, and that of the 'Interior Basin' (Ohioan fauna)." Although several species belonging to the Interior Basin fauna continue in an upstream direction in the main portion of the Tennessee to stations above Muscle Shoals, there is a distinct scarcity of the Cumberlandian elements below these shoals. Ortmann (1925, 366) recognized this situation: "The stretch of the Tennessee between Muscle Shoals and Dixie is unknown, but the lower boundary of the Cumberland fauna must be located in this region." With the additional distributional data available (Table 1) it is possible to estimate more closely the lower boundary of the Cumberlandian fauna. Unfortunately, we lack the details necessary to establish the exact limit of the region in which the Cumberlandian elements occur, but it is evident from the data presented here that no Cumberlandian species have been observed below Muscle Shoals. Since somewhat similar ecological conditions persisted formerly for some distance below Muscle Shoals, we have reason to believe that Cumberlandian elements may have occurred as far downstream as the Colbert Shoal area. If this assumption is correct the limit is somewhere in the vicinity of the former town of Riverton. Dr. Walter B. Jones, State Geologist of Alabama, in a letter concerning this matter states: "From a purely geological standpoint, it is my opinion that the changes should occur in the vicinity of the Bear Creek area" (see map).

The fact that the "break" between the Cumberlandian fauna and the Interior Basin fauna occurs in the region of the "Fall Line" should not be overlooked. The distinct change in the naiad fauna of this region may be correlated with a change in the geological and physiographical conditions in this same portion of the lower Tennessee River. From the meager data at hand the transition between these two major faunal elements appears to be correlated with the appearance and disappearance of the Tuscaloosa formation, which according to Fenneman (1938, 67) is adjacent to the Fall Line in this region. The faunal evidence for the transition may be seen in Table 1, particularly among the Cumberlandian elements, which are conspicuously absent below Muscle Shoals in the lower Tennessee. Furthermore, certain of the Interior Basin species, such as *Fusconaia ebenus, Fusconaia subrotunda,* and *Quadrula quadrula,* disappear suddenly in the main portion of the Tennessee at about this same region. It is of special interest in this connection that a

similar correlation (van der Schalie, 1938, 21) has been found in the Cahaba River of Alabama among certain species which were restricted to the coastal-plain zone of that stream.

The species that may now more conclusively be considered as belonging to the naiad fauna of the "Interior Basin" in the lower Tennessee River are as follows:

Unionidae:

1. *Fusconaia ebenus* (Lea)
2. *Fusconaia subrotunda* (Lea)
3. *Megalonaias gigantea* (Barnes)
4. *Amblema costata* Rafinesque
5. *Quadrula pustulosa* (Lea)
6. *Quadrula quadrula* Rafinesque
7. *Quadrula metanevra* Rafinesque
8. *Tritigonia verrucosa* (Rafinesque)
9. *Cyclonaias tuberculata granifera* (Lea)
10. *Plethobasus cyphyus* (Rafinesque)
11. *Plethobasus cooperianus* (Lea)
12. *Pleurobema cordatum* (Rafinesque)
13. *Pleurobema cordatum pyramidatum* (Lea)
14. *Elliptio crassidens* (Lamarck)
15. *Elliptio dilatatus* (Rafinesque)

Lampsilinae:

16. *Obliquaria reflexa* Rafinesque
17. *Obovaria retusa* (Lamarck)
18. *Obovaria olivaria* (Rafinesque)
20. *Proptera alata* (Say)
21. *Ligumia recta latissima* (Rafinesque)
22. *Lampsilis anodontoides* (Lea)
23. *Lampsilis orbiculata* (Hildreth)
24. *Truncilla truncata* Rafinesque
25. *Truncilla donaciformis* (Lea)

In the above list, seven species (Numbers: 2, 8, 19, 20, 21, and 22) are relatively uncommon although they unquestionably inhabit the lower Tennessee; the remaining eighteen species are to be considered as common to that region. It is also of interest to note the complete absence of species of the Anodontinae. No explanation for this condition is available, although in general it has been known for some time that species belonging to the Anodontinae are much more common in the Ohio River and to the north than in drainages to the south of that river. Perhaps the impounding of waters in the lower portion of the Tennessee after the completion of the Gilbertsville Dam at Paducah may result in a great increase in the number of species of Anodontinae, which will adapt themselves to the altered conditions.

The information given here essentially agrees with the data presented by Ortmann in 1925. The Interior Basin fauna consists of twenty-five species. Not a single species belonging to the Cumberlandian fauna inhabits any portion of the lower Tennessee below the former town of Riverton, Alabama. Finally, there is a striking correlation between the place at which the faunal "break" occurs and the geological and physiographical features at the edge of the Tuscaloosa formation and the "Fall Line."

## REFERENCES

FENNEMAN, N. M. 1938—Physiography of Eastern United States. New York, McGraw-Hill Book. Co.

HINKLEY, A. A. 1906—Some Shells from Mississippi and Alabama. Nautilus **20**:52-55.

ORTMANN, A. E. 1924—Mussel Shoals. Science **60**:565-66.

———1925—The Naiad Fauna of the Tennessee River System below Walden Gorge. Amer. Midl. Nat. **9**:321-71, 1 map.

ORTMANN, A. E. AND BRYANT WALKER. 1922—On the Nomenclature of Certain North American Naiades. Occ. Papers Mus. Zool. Univ. Mich. **112**:1-75.

VAN DER SCHALIE, HENRY. 1938—The Naiades (Fresh-water Mussels) of the Cahaba River in Northern Alabama. Occ. Papers Mus. Zool. Univ. Mich. **392**:1-29, 1 map.

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# Some Pycnogonids Found off the Coast of Southern California

Joel W. Hedgpeth

Few collections of Pycnogonids from the offshore waters of California have been made, and this paper is the first detailed account of some of the species from that region although several of the collections were made as long ago as 1915. For the material discussed in this paper I wish to thank Mr. Percy S. Barnhart, Curator of the Museum of the Scripps Institution of Oceanography, who loaned me a collection gathered over a period of years, and Dr. George S. Myers of Stanford University for the Pycnogonids dredged during the Crocker-Stanford Expedition on the "Zaca" off the coast of southern California in September, 1938. I am also indebted to Dr. Carl D. Duncan of San Jose State Teachers College, Dr. G. E. MacGinitie, Director of the Kerckhoff Laboratories of the California Institute of Technology at Corona Del Mar, and Mr. E. F. Ricketts of the Pacific Biological Laboratories at Pacific Grove for specimens of *Nymphopsis spinosissimus* (Hall), and to Mr. H. V. M. Hall of Berkeley, California, for suggestions concerning the status of this species.

Four species, two of them new, have been dredged from moderate depths in the general vicinity of the Santa Barbara Islands and Catalina Island. The most common species appears to be *Nymphon solitarium* Exline, described from Puget Sound, and of the 44 specimens in the two collections of dredged material, 26 are of this species. *Anoplodactylus erectus* Cole is next, represented by fourteen specimens. This is also a littoral form, found in tide pools and hydroid colonies on wharf pilings from Monterey Bay to San Diego. Additional data concerning its distribution will be found in the table of localities for *Nymphon solitarium*, below. The other two species, each represented by two specimens, are described below.

### Genus NYMPHON Fabricius

### *Nymphon solitarium* Exline 1936

The series of *Nymphon solitarium* from the collections is rather uniform and shows little variation from the original description. The eye tubercle is more acutely pointed in some specimens and in one the point is bent distinctly forward at the apex of the tubercle. The abdomen is sometimes as long as the eye tubercle. The proboscis in several examples has more of a constriction in its distal third than Exline's figure. The general body proportions are fairly consistent, although two specimens are slenderer than the rest, with a correspondingly narrow proposcis. A representative series of nine specimens, from the San Pedro Channel (See Crocker-Stanford station 28, below in table 1), has been deposited in the Stanford Natural History Museum. (S.N.H.M., no. 3210).*

TABLE 1

Distribution of *Nymphon solitarium* off southern California

(Scripps Institution of Oceanography collection.)

| Coll. No. | Date | Location | Depth | Bottom type |
|---|---|---|---|---|
| 1027 | 7-19-15 | 32° 53′ N, 118° 24′ W. ......... | 605 meters | green mud |
| 1186 | 7-2-16 | 32° 50′ .3 N, 117° 21′ W. .. | 110-185 meters | green mud |
| 1189‡ | 7-2-16 | 32° 49′ .8 N, 117° 24′ .8 W. | 330-365 meters | green mud |
| 1288* | 7-16-16 | 32° 49′ .7 N, 117° 18′ .6 W. | 73-92 meters | rocky |
| 1127-D54 | 7-30-17 | ¾ mi. West of Torrey Pines. | 75-100 feet | green mud |
| Sta. No. | | (Crocker-Stanford Collection.) | | |
| 5*† | 9-12-38 | Off Pt. San Luis, 35° 08′ N, 120° 52′ W. .... | 56 fathoms | rock (?) |
| 10 | 9-13-38 | Santa Barbara Channel, 34° 09′ N, 120° 04′ W. ... | ? | green mud |
| 28* | 9-17-38 | San Pedro Channel, 33° 35′ N, 118° 20′ W. ... | 100-150 fathoms | green mud |
| 30 | 9-17-38 | Santa Catalina, off Avalon, 33° 23′ N, 118° 20′ W. ... | 80 fathoms | dead and bleached corallines |
| 33* | 9-18-38 | SW end Catalina I., 33° 17′ N, 118° 21′ W. ... | 45 fathoms | green mud |

(Since the completion of this paper a collection of *N. solitarium* made by Dr. Rolf L. Bolin of the Hopkins Marine Station, Pacific Grove, has come to light. It was made on 11-12-35 off Pt. Sur, 36° 20′ 45″ N, 122° 06′ 15″ W., at 208 fathoms.)

* With *Anoplodactylus erectus* Cole.
‡ With *Colossendeis californica* new species.
† With *Pallene pacifica* new species.

## Genus COLOSSENDEIS Jarzynsky

### **Colossendeis californica** sp. nov.

Pl. 1, Figs. *a-e*

Holotype ♂, U. S. Nat. Mus. No. 78022.

Paratype ♂, U. S. Nat. Mus. collection.

Type Locality: 32° 29′ .8 N, 117° 24′ .8 W., 330 meters, green mud, 7-2-16. (Scripps Institution of Oceanography collection no. 1189).

Body distinctly segmented, segments dilated posteriorly to ring like swellings; trunk three fifths as long as proboscis, lateral processes distinct and separated by a distance of two thirds their thickness. Proboscis large, longer than body, spindle shaped, two thirds as wide as body in its broadest part, bent ventrally in the first fifth of its length and constricted basally to a short, stout petiole. Eye tubercle near anterior end of first trunk segment, as high as length of segment, leaning slightly forward and tapering to a fine point. Eyes well developed, in the basal third of the tubercle. Abdomen very short

* Among the Pycnogonids sent by Dr. G. E. MacGinitie for identification is a specimen of *Nymphon turritum* Exline which establishes an interesting distribution record for that species, the first record, I believe, outside of Puget Sound, the type locality: "Punuk Island, off St. Laurence I., Bering Sea, 15 fathoms. Grey sand, mud. 7-15-37. MS 'Stranger,' F. E. Lewis, owner. (collected by) W. Williams."

and blunt, between last pair of lateral processes. Palpus one third longer than proboscis, with a few scattered setae on the terminal segments. Lengths of the segments in millimeters: 0.3, 4.0, 0.4, 1.35, 0.4, 0.3, 0.6, 0.4. Ovigers one third as long as legs, last four segments coiled, bearing several rows (seven in the terminal segment) of simple spines. Oviger terminated by a minute but well developed and finely toothed chela. Lengths of the segments, in millimeters: 0.15, 0.2, 3.0, 0.6, 2.5, 0.5, 0.5, 0.5, 0.4. Legs moderately long, slender, without ornamentation or conspicuous setae. Lengths of the segments, in millimeters: 0.65, 0.65, 6.0, 7.25, 4.75, 1.8, 1.6, 1.5.

Measurements:

| | Holotype | Paratype |
|---|---|---|
| proboscis* | 5.50 mm. | 6.0 mm. |
| trunk | 3.75 | 4.0 |
| palpus | 8.35 | 8.0 |
| oviger | 8.15 | 9.25 |
| third leg | 24.20 | 28.25 |
| eye tubercle | 1.25 | 1.5 |
| abdomen | 0.10 | 0.1 |

This species belongs to the small group of *Colossendeis* species with distinctly segmented bodies, composed of *C. articulata* Loman 1908, *C. dofleini* Loman 1911, and *C. germanica* Hodgson 1927. It can be distinguished from all these forms by the extremely high and slender eye tubercle and the petioled, spindle shaped proboscis. *Colossendeis californica* appears to be most closely related to *C. dofleini* Loman, a Japanese form, but differs from it in the following respects: In *C. californica* the proboscis tapers distally as well as proximally, while in *C. dofleini* it is blunt distally. In *C. dofleini* the eyes appear to bulge out on the tubercle, which is not the case with *C. californica*. *C. dofleini* is described as having but one row of spines on the terminal segments of the oviger and with a weak terminal claw, while there are several rows of spines and a well developed chela on the terminal segments of the oviger of *C. californica*.

### Genus Pallene Johnston

### **Pallene pacifica** sp. nov.

Pl. 1, Figs. *f-i*, Pl. 2, Figs. *j-l*.

Holotype ♀, Stanford Natural History Museum no. 3211.

Paratype ♀, Stanford Natural History Museum no. 3212.

Type Locality: Off Pt. San Luis, 35° 08′ N, 120° 52′ W, 56 fathoms, rock (?). (Crocker-Stanford Expedition, station 5).

Body moderately slender with lateral processes separated by about half their width, segmentation of all segments distinct; the length of the proboscis and neck anterior to the eye segment as viewed from above equal to the length of the trunk posterior to the eye tubercle. Neck broadened at base of chelifores to almost the width of the first lateral processes. Chelae stout, a little

* Measurement of proboscis is the chord from base to tip without considering the curvature.

longer than twice their width, flattened and bearing a few sparsely scattered setae, minutely toothed on both fixed and movable joints; scape barely overreaching the proboscis. Proboscis short and blunt, apparently as wide as long from above, a little longer than wide from below, swelling slightly distally. Eye tubercle erect, subconical or rounded, with large eyes. Abdomen erect or nearly so, as high as eye tubercle, with a depression at the apex giving it a slightly bilobed appearance. Ovigers little over twice the trunk length and about one fifth length of legs, the lateral distal protuberance on the fifth joint of the female small, not visible from all angles, terminal joints coiled and bearing a single row of finely denticulate, leaf like spines. Lengths of segments, in millimeters: 0.2, 0.2, 0.25, 0.25, 0.3, 0.5, 0.4, 0.3, 0.3 0.2. Legs about five times as long as body including proboscis, without conspicuous ornamentation or setae. Tarsus with terminal claw and two auxiliary claws three fourths as long as terminal claw, terminal claw almost as long as tarsus. Sole with stout spines at base. Lengths of segments in millimeters: 0.3, 1.0, .5, 2.6, 2.1, 2.9, 0.1, 0.6; terminal claw, 0.4; auxiliary claw, 0.3.

Measurements:

| | Holotype | Paratype |
|---|---|---|
| proboscis | 0.5 mm. | 0.5 mm. |
| neck | 0.8 | 0.8 |
| trunk | 1.3 | 1.3 |
| chela | 0.7 | 0.5 |
| scape | 0.4 | 0.4 |
| oviger | 2.9 | 2.75 |
| third leg | 10.3 | 9.9 |
| eye tubercle | 0.2 | 0.2 |
| abdomen | 0.2 | 0.2 |

This species, like *Pallene margarita* Gordon 1932, and *P. emaciata* Dohrn 1881, has a completely segmented trunk. It is distinct from *P. margarita* in general appearance, the robust and evenly swollen neck at the base of the proboscis for example, and has much longer and slenderer tarsal claws than *P. emaciata*. The local species of *Pallene*, *P. californiensis* Hall 1913, is more compact, has the last two trunk segments indistinctly segmented, and has a much broader neck than *P. pacifica*. The femoral joints of the female of *P. pacifica* are apparently not as swollen as in other species of this genus.

Genus NYMPHOPSIS Haswell
*Nymphopsis spinosissimus* (Hall).
*Ammothella spinosissima* Hall 1911.
Pl. 2. Figs. *m-r*.

Neotype ♂, U. S. Nat. Mus. no. 78023.

Type locality: Not specified, probably Laguna Beach. Neotype from Corona Del Mar, 12-17 fathoms, collected by G. E. MacGinitie, 3-27-38. (Six miles north of Laguna Beach).

This species, described from a microscope slide mount which has since been lost, is herewith redescribed from an unmounted neotype collected a few miles north of the probable type locality.

Body circular, lateral processes distinctly separated (not fused as described by Hall), in the females apparently more so than in the males, and bearing on each corner of their distal margins spinous protuberances or tubercles of nearly equal size. Trunk unsegmented, with three erect dorsal tubercles bearing numerous spines but no terminal spines. Eye tubercle almost as high as dorsal trunk tubercles, abruptly pointed but without a terminal spine, eyes near the apex. Proboscis three fourths as long as trunk, directed ventrally, oval shaped. Abdomen as long as trunk, arched dorsally and bearing a series of spinous tubercles in pairs. Chelifores slightly longer than proboscis from above, three jointed, the second joint or scape weakly trumpet shape and studded with several spinous tubercles. Third joint rudimentary, in some specimens not apparent from above, in others completely submerged within the scape, with a terminal spine. Palpi nine jointed, one third longer than proboscis, with a protuberance on the middle of the fourth joint bearing a single spine. Second joint longest, fourth joint almost as long as second. Last five joints of diminishing size, bearing setae somewhat longer than the segments themselves. First and second joints without setae, a few on the third and fourth joints. Ovigers nine jointed, the third distinctly curved, penultimate segment of the male with several setae which are longer than the terminal segment; setae in female short. Lengths of segments of oviger in millimeters approximately as follows: 0.3, 0.3, 0.6, 0.9, 0.6, 0.2, 0.19, 0.17, 0.1. Legs short and stout, with two rows of prominent spinous tubercles with long terminal spines on the coxal and tibial joints, those on the second tibial joint longer and bowed laterally. Tarsus with large stout claw two thirds as long as tarsus, no auxiliary claws. Genital openings on prominent ventral protuberances of second coxal joints. Lengths of leg segments in millimeters approximately as follows: 0.6, 0.8, 0.5, 1.85, 1.6, 1.5, 0.2, 1.0.

Measurements (approximate, as seen from above without straightening legs).

Neotype

| | | | |
|---|---|---|---|
| proboscis | 1.5 | chelifore | 1.6 |
| trunk | 2.0 | palpus | ? |
| abdomen | 1.5 | oviger | 3.36 |
| dia. eye tubercle | 0.2 | third leg | 6.15 |

Hall (1911, p. 99) remarked on the similarity of this species to the figures of *Nymphopsis muscosus* Loman (1908), but commented: ".... the arrangement of these (multi-spine bearing) processes as well as generic characters show that there can be no possible connection." The species figured by Loman, however, does not belong to the group of *Nymphopsis* species most closely related to the one in question, and from Williams' (1933) descriptions and figures of *Nymphopsis acinacispinatus* from Queensland, it is evident that the species described by Hall as *Ammothella spinosissima* should really be called *Nymphopsis spinosissimus*. It is very similar to *N. acinacispinatus* in gross appearance and spiny armature, but differs in having the spine bearing processes of the tibial joints more evenly distributed instead of restricted to the distal portions of these joints as is apparent from Williams'

figure of *N. acinacispinatus*. In *N. spinosissimus* the abdomen is not directed ventrally and the first pair of dorsal spinous tubercles on the abdomen is not accompanied by a smaller, secondary pair. The peculiar three lobed spines which Williams considers to be characteristic of this genus, although Gordon (1932) has described a species, *N. denticulata*, in which they are lacking, are well developed in *N. spinosissimus*. The rudimentary chelae of *N. acinacispinatus* are apparently (described from a single ♂ specimen completely submerged within the scape, a condition found in one specimen of the series of seven *N. spinosissimus* from various parts of the California coast, but in others it is a distinct third joint although in some it is not clear from directly above. This three jointed appearance has been noted in other species of *Nymphopsis*, *N. denticulata* Gordon and *N. abstrusus* Loman 1923, both described from single specimens, and it is apparent that the two jointed condition cannot be relied upon as a hard and fast generic character, but the trumpet or cup like distal swelling of the scape or second joint appears to be constant.

With this revision the range of the genus *Nymphopsis* is extended to the western coast of North America. It had previously been known from Australia, the southern part of Japan, Venezuela, East Falkland Islands and Capetown, South Africa. In California *Nymphopsis spinosissimus* has been collected at Pacific Grove, Carmel, Corona Del Mar and Laguna Beach. It is probably an inhabitant of the region just beyond the low tide level since it has only been collected at very low tides or by dredging.

## REFERENCES

DOHRN, A. 1881—Die Pantopoden des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Fauna und Flora des Golfes von Neapel Monographie **3**:1-252, 18 pls.

EXLINE, H. I. 1936—Pycnogonids from Puget Sound. Proc. U. S. Nat. Mus. **83**:413-422, 1 pl.

GORDON, I. 1932—Pycnogonida. Discovery Reports **6**:1-138, 75 figs. in text.

HALL, H. V. M. 1912—Studies in Pycnogonida I. Rep. Laguna Mar. Lab. **1912**: 91-99, 4 figs. in text.

———1913—Pycnogonida from the coast of California. Univ. Calif. Publ. Zool. **11**(6):127-142, pls. 3-4.

HODGSON, T. V. 1927—Die Pycnogoniden der Deutschen Suedpolar Expedition 1901-1903. Deutsche Sued—Polar Exp. **19**(Zoology 11):305-358, 17 figs. in text.

LOMAN, J. C. C. 1908—Pantopoden der Siboga-Expedition. Siboga Exp. **40**:1-188, pls. I-XV, 4 figs. in text.

———1911—Japanische Podosomata. Beitr. zur Naturgesch. Ostasiens. Abh. Bayer. Akad. Wiss., Suppl. **2**(4):1-18, 2 pls.

———1923—Subantarctic Pantopoda from the Stockholm Museum. Arkiv før Zool. **15**(9):1-13, 5 figs. in text.

WILLIAMS, G. 1933—On *Nymphopsis acinacispinatus* a new Pycnogonid from Queensland. Ann. and Mag. Nat. Hist. (10)**12**:173-180, 6 figs. in text.

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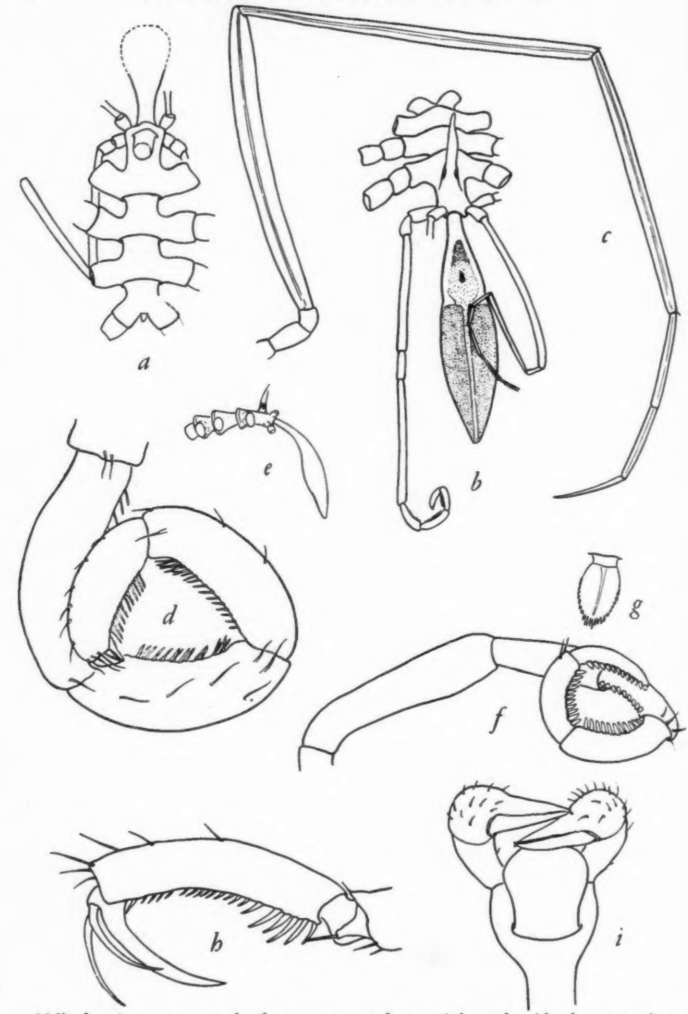


(All drawings were made from unmounted material, and with the exception of figs. *e* and *l*, with the aid of a camera lucida. Magnifications approximate.)

PLATE 1. *Colossendeis californica* sp. nov. (Drawings of holotype). Fig. *a*. Dorsal aspect of trunk, x10; *b*. Trunk and proboscis, anterior dorsal view, x10; *c*. Third leg, x7.5; *d*. Terminal segments of oviger, x60; *e*. Sketch of side view, x3. *Pallene pacifica* sp. nov. (Drawings of holotype). *f*. Oviger, segments 5-10, x10; *g*. Spine from oviger, x100; *h*. Tarsus, x60; *i*. Ventral view of proboscis and chelae, x26.

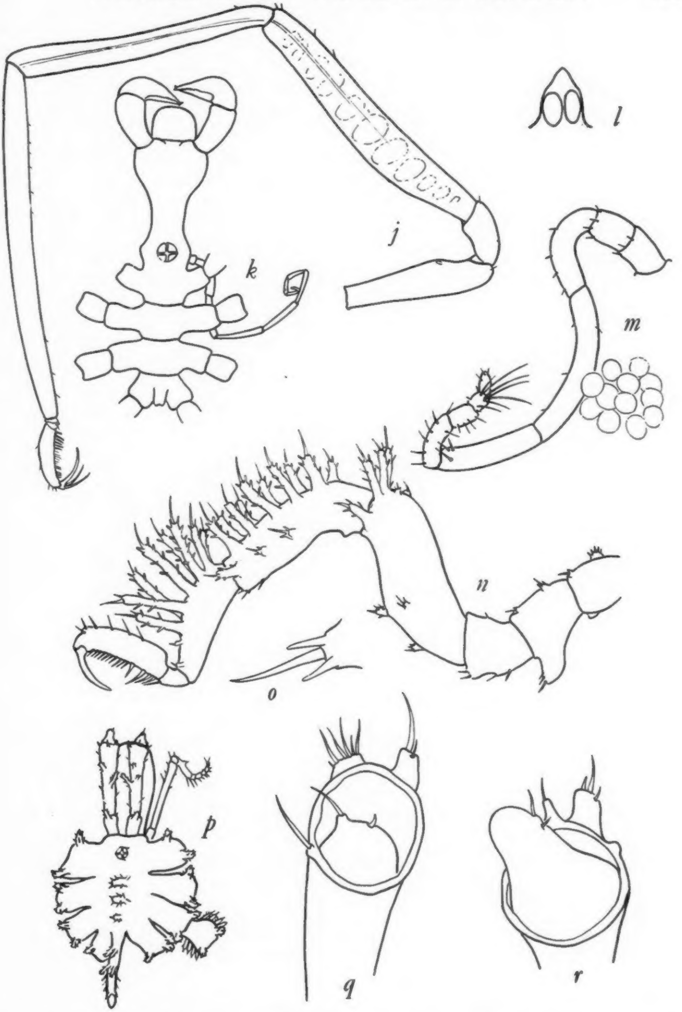


PLATE 2: *j*. Third leg, x16; *k*. Dorsal view of body, x16; *l*. Eye tubercle, side view, x45. *Nymphopsis spinosissimus* (Hall). (Drawings as noted). *m*. Oviger of ♂, from dissected specimen, x20; *n*. Third leg of ♀, from dissected specimen, x15; *o*. Three lobed spine, from above, x100; *p*. Dorsal view of body, neotype (tilted slightly to left), x7.5; *q*. Chelifore of ♂, from dissected specimen, x37.5; *r*. Chelifore of ♀, from dissected specimen, x37.5.

# Observations on Eubranchipus vernalis in Southwestern Ontario and Eastern Illinois

M. S. Ferguson

*Eubranchipus vernalis* Verrill, 1869, one of the larger and more widely distributed species of North American Phyllopoda, which occurs in the northern United States from the Middle West to New England, was first recorded in Canada from southwestern Ontario in 1935 (Ferguson, 1935). Since the initial collection, in April, 1932, this crustacean has been found by the writer on different occasions during the past seven years in several temporary pools near London and St. Thomas, Ontario. While making these collections some interesting observations were made on the habits and life history of this form. These observations are supplemented with references to the literature, and with some additional notes made on *E. vernalis* from collections taken in eastern Illinois during the years 1935-1937, while the writer attended the University of Illinois at Urbana.

In the London and St. Thomas districts the writer has collected *E. vernalis* from six bodies of water. As reported previously (Ferguson, 1935), it appears to inhabit the deeper temporary pools. If the pools were not sufficiently deep (over two and one-half feet in every one examined by the writer), the ice might extend to the bottom during the severe winters sometimes experienced in southwestern Ontario. Consequently, since the eggs of this fairy shrimp hatch in the fall, the young would probably perish. This may be a controlling factor in determining the pools in which one can collect *E. vernalis*.

Usually the water in the deeper pools is very clear and, in every one from which the writer has taken fairy shrimps, there has been an abundance of algae during the spring. In 1932 such filamentous algae as Spirogyra, Zygnema, Vaucheria, and Oedogonium were identified from one pool. Along with *E. vernalis* were collected many aquatic animals such as: cladocerans, copepods, ostracods, amphipods, mayfly naiads and other water insects (both immature and mature), together with a multitude of protozoans and small invertebrate forms. These animals and plants are the ones a collector finds commonly in many pools during late winter, spring, and early summer months. They develop from an immature to a mature condition, in a shorter or longer time, and then begin to prepare for their contribution to the pond life of the following year. Both the plants and animals must ensure, through some means, that the race will survive during the unfavorable period when the pool is dry, so that a succeeding generation can enjoy its interesting but usually brief existence. Some of the ways in which Nature regulates the life span of *E. vernalis* will be noted later.

In the writer's experience *E. vernalis* was never abundant in a pool and in

only one case was it accompanied by another fairy shrimp. In this particular pool, however, specimens of *Pristicephalus bundyi* (Forbes, 1876) were present. It is often rather difficult to locate the individuals of *E. vernalis* due to their coloration, and also their habit of remaining, for the most part, near the bottom of the pool. Both the males and females are very beautiful creatures as they proceed gracefully through the water by rhythmical movements of the swimming appendages. Upon close examination the living males, averaging about 23 mm. in length, are found to possess very large pale green heads, white first antennae, yellowish-green bodies, and amber green swimming thoracic appendages, the edges of which are fringed with orange. The large clasping second antennae are amber in color and the cercopods and posterior tip of the abdomen a reddish purple. The living females, which also average about 23 mm. in length, have much smaller heads, almost rudimentary second antennae, and are usually darker in color. The heads are greyish or amber green with green markings, the body a yellowish green, and the swimming thoracic appendages brownish with dark green edges. Behind the swimming appendages is located the ovisac, which, in the mature female, is filled with spherical brown eggs. The posterior part of the abdomen and the cercopods, as in the males, are purplish. In older specimens of both sexes the tips of the two cercopods may be broken away, so that only very blunt appendages remain.

The darker coloration of the females makes it difficult for one to see them in the water, especially when they are near the bottom of the pool, where most mature individuals are found. The mature females, as has also been noted by the writer in observing the females of *P. bundyi*, are very active and more difficult to collect with a net than the males. The males of *E. vernalis* swim about in the pool sometimes fairly near the surface. However, if there is a thick growth of green algae in the water they then become more difficult to see, due to the lack of color contrast. Usually, if one looks into the water at one selected spot for some minutes, the slow cruising motion of the fairy shrimps will betray their presence. Since specimens of *E. vernalis* are never very abundant in a pool, it is advisable to collect them individually from the water, as they swim into view, by means of a small dip net or strainer. However, if one makes random sweeps in the water with a large dip net, or tows a plankton net some distance, he may be rewarded with a few specimens. The latter method of collecting works to better advantage when one is searching for the immature stages of *E. vernalis*, since many of these individuals are closer to the surface and are not nearly as active and capable of avoiding the mouth of a net as the more mature ones.

Various observers have noted the peculiar phenomenon that fairy shrimps may be present in a pool one year, while the next year they are apparently absent. The writer has made such observations in the case of *E. vernalis* in studies carried on while at the University of Illinois. In the spring of 1936 these fairy shrimps were found in considerable numbers in two pools along the Salt Fork River at Homer Park, near Homer, Illinois. None was collected from these same pools when visited both in February and on March 20, 1937.

During this year the life in these bodies of water was possibly disturbed by early spring flood conditions when the nearby Salt Fork River overflowed its banks and water moved over a large low-lying area in which the pools were located. If, as was probably the case, the fairy shrimps were already hatched from the eggs, they could very readily be carried away in the flood waters. In one pool near London, Ontario, where the writer has had a better opportunity to study the annual occurrence of *E. vernalis,* this form has been found every spring collections were made (four different years, 1932, 1933, 1934, 1938). The pool is not affected by flood conditions as were those pools at Homer Park, Illinois. Consequently, there would likely be a greater chance of the fairy shrimp population remaining more or less unchanged. The writer has noted, however, that the numbers of *E. vernalis* in this pool do vary over a period of years. In this same pool *P. bundyi* has been found and its populations have also tended to fluctuate over the period of years observations were made. No doubt various factors play an important role in regulating the phyllopod population of any particular body of water.

As mentioned previously, the eggs of *E. vernalis* hatch in the fall after the rains have filled the pools (late October or early November), and the fairy shrimps develop slowly during the winter under the ice. This is borne out in the work of Packard (1883) and by personal studies of the writer both in southwestern Ontario and eastern Illinois. No intensive study has been made by the writer of growth in *E. vernalis* from the time the eggs hatch in the fall till the mature condition is attained in the spring.

Fully mature females, having the ovisacs filled with eggs, were collected from one pool in the London district during the second week of April in 1932. Unfortunately, it was impossible to make regular trips to this pool in order to note the approximate date at which the fairy shrimps disappeared. On May 20th none was seen in two other pools a few miles away where *E. vernalis* had been previously collected that year. For this part of Ontario, it is probably safe to assume that the normal span of life of *E. vernalis,* as swimming individuals, is from about the first of November until early in May, i.e., roughly six months. Packard (1883) gives similar dates for the life span of this form in the United States. It is commonly believed that as the temperature of the water in a pool becomes warmer in the spring the environment becomes more unfavorable for the fairy shrimps. Possibly, the warming of the water has brought them to sexual maturity and, as a natural process, they die when their main life function, that of providing for another generation, is completed. The writer has experimental evidence, from work done at the University of Illinois, which shows that with the phyllopod *Eubranchipus serratus* Forbes, 1876, every specimen maintained in the laboratory at a constant temperature of 8° C., while the water from which these individuals were collected became warmed above 20° C., lived for a period of three weeks after individuals of the species had disappeared from the above mentioned pool. With this form, and as may likely be true of many other species of fairy shrimps, temperature is probably an important factor in controlling the length of life. However, the specimens which were kept under controlled conditions

in the laboratory may also have been affected by factors other than temperature, such as food supply, chemical conditions in the water, etc.

Although the normal life span of *E. vernalis* is approximately six months, the writer is able to show that under unusual circumstances it may be much shorter. In southwestern Ontario the autumn and early winter period of 1933-1934 was very dry, with little rain or snow, and as a result the temporary pools contained no water until heavy rains came early in March, 1934. In the one particular pool from which *E. vernalis* has been collected for several years no water was present till about March 3rd. On April 8th of that year large numbers of immature fairy shrimps ranging from 10 to 15 mm. in length were present. Later observations showed that these phyllopods matured and died about the normal time of year, i.e., early in May. During this year, therefore, the life span of *E. vernalis* in this part of Ontario was only about two months.

The forms collected on April 8, 1934, were much less mature than those taken from the same pool April 17, 1932, and from another pool April 9, 1932. The specimens collected in 1932 had probably lived under the ice during the winter and would, therefore, have had a much longer period for development. A careful study of the growth of these fairy shrimps might show that when they are newly hatched there is a period of rapid development for a short time, and then a gradual approach to maturity during the winter. Specimens collected on December 1, 1937, from under the ice on the same pool which was dry until March 3, 1934, ranged from about 10 to 15 mm. in length. Since the temporary pools were filled with water about November 1, 1937, these specimens were probably one month old. Their size range agreed rather closely with that of the specimens collected in the same pool April 8, 1934, about one month after it was filled that particular year. It is difficult to compare the development of these fairy shrimps in the fall and spring, since on the one hand, environmental conditions are probably becoming more adverse for growth, while on the other they are becoming more favorable. For a better knowledge of this and similar problems, careful studies should be made over a period of years of the conditions in a series of pools.

The writer wishes to acknowledge the cooperation of Dr. Ralph Dexter in making the observations on the Illinois fairy shrimps mentioned in this paper.

## REFERENCES

(1) Ferguson, M. S. 1935—Three species of Eubranchipus new to Canada. Can. Field Nat. **49**:47-49.

(2) Packard, A. S. 1883—A monograph of the phyllopod crustacea of North America with remarks on the order Phyllocarida. 12th Ann. Rept. U. S. Geol. and Geog. Surv. Terr. :295-590.

Princeton, N. J.

# New Forms of the Genus Lituola in Mississippi

Frederic F. Mellen and Alta Ray Gualt

In this paper *Lituola taylorensis* Cushman and Waters of the Prairie Bluff (Upper Cretaceous) formation, *L. erecta* n. sp. of the Clayton (Midway, Eocene) formation, and *L. erecta distincta*, n. subsp., of the Porters Creek (Midway, Eocene) formation are described and illustrated from Mississippi. *L. taylorensis* Cushman and Waters marks a zone near the base of the Prairie Bluff formation; *L. erecta* is abundant in the thin Clayton formation and is also an excellent horizon marker; *L. erecta* subsp. *distincta* is present in the calcareous basal part of the Porters Creek formation. The recurrence of *L. taylorensis* in the Prairie Bluff formation of Navarro age extends the known range of the species.

Other than the work of Stephenson (1914, 1917, 1934, 1935, 1937) on the Cretaceous, there are no published reports on the paleontological zonation of the Upper Cretaceous and basal Eocene beds of Mississippi.

The marine Upper Cretaceous of Mississippi is represented in the outcrop by 250-550 feet of Eutaw glauconitic sands and clays, 250-900 feet of Selma chalk, 100-400 feet of Ripley sand, clay and impure limestone, 0-50 feet of Owl Creek marl, and 0-50 feet of Prairie Bluff chalk (Stephenson, 1937). In Union County the Owl Creek marl, typically developed to the north in Tippah County merges laterally into the Pairie Bluff chalk, which is chiefly a calcareous clay even as far north as Pontotoc County. The Prairie Bluff and the Owl Creek formations are contemporaneous and constitute the youngest Cretaceous beds in the State.

In designating the Prairie Bluff and Owl Creek units as formations, Stephenson and Monroe (1937) have recognized a wide-spread unconformity separating the Ripley formation from these overlying strata. Previously, Stephenson (1917) regarded the Prairie Bluff unit as an upward and lateral continuation ("tongue") of the Selma chalk, but Guest (1935) has demonstrated by lithologic studies that facies of the Ripley formation completely separate the "Oktibbeha member of the Selma" (Prairie Bluff formation) from the main body of underlying Selma chalk.

The Midway (Eocene) series of Mississippi is divided into the Clayton and Porters Creek formations, both marine. The Clayton formation in northern Mississippi is composed of 25-50 feet of highly fossiliferous arenaceous limestone and cross-bedded glauconitic and non-glauconitic sand. It is represented by a very thin zone of 0-10 feet of argillaceous calcareous fossiliferous sand from Chickasaw County to the Alabama state line. The Porters Creek clay is 250-500 feet thick and is composed chiefly of very fine-grained silty carbonaceous montmorillonitic clay. It is normally arenaceous and calcareous toward its gradational contact with the underlying Clayton, and in most places is highly micaceous and arenaceous near the top.

Field investigations of Cretaceous and Midway beds from Alabama to Tennessee indicate that the three Lituolas described in this paper will prove to be valuable stratigraphic subsurface markers as well as surface markers. They are narrowly restricted, two of the forms are very abundant, and, unlike most Foraminifera, they are large enough to be safely identified in the field without a lens. Although the forms are found on the outcrop within a 100-foot vertical section, the Cretaceous-Eocene contact which intervenes marks what is perhaps the greatest hiatus in the Mississippi Embayment sedimentary record, and the recurrence of the genus in this manner is noteworthy. The form described as *L. taylorensis* Cushman and Waters, seems to be restricted to a zone about 15 feet thick at the base of the Prairie Bluff formation. *L. erecta,* n. sp., has not been found outside the Clayton formation, and *L. erecta* subsp. *distincta,* n. subsp., is seemingly restricted to the calcareous basal portion of the Porters Creek clay but is not a persistent marker.

### *Lituola taylorensis* Cushman and Waters

Fig. 1; Fig. 4, bottom row.

The specimens differ from the Taylor forms in size. The average size approaches the maximum of the Taylor forms. The maximum length is 6 mm.; width of coil 3.5 mm.; thickness 1.75 mm.

*L. taylorensis* has been found in Oktibbeha County on the eroded areas in the golf course just north of the campus of Mississippi State College, NW. 1/4 sec. 1, T. 18 N., R. 14 E., in the gullies near the tops of the hills at Stoney Point 3.5 miles northwest of Starkville, SW 1/4 sec. 16, T. 19 N., R. 14 E., one-quarter mile northwest of the courthouse in Starkville, and in the gullies of the south wall of Catalpa Creek, NE. 1/4 sec. 25, T. 18 N., R. 14 E. It is common in Clay County 4 miles northwest of Cedar Bluff near the center of sec. 12, T. 20 N., R. 12 E.

Its stratigraphic range at Stoney Point is through 10 or 15 feet of coarse,

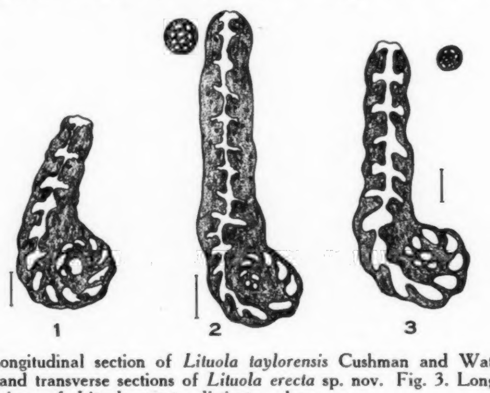


Fig. 1. Longitudinal section of *Lituola taylorensis* Cushman and Waters. Fig. 2. Longitudinal and transverse sections of *Lituola erecta* sp. nov. Fig. 3. Longitudinal and transverse sections of *Lituola erecta distincta* subsp. nov.

extremely glauconitic, fossiliferous sand near the base of the Prairie Bluff formation. A quarter of a mile northwest of the Oktibbeha County courthouse the fossil is found in beds that contain quartz grit up to 1/4-inch diameter. It is found less than 20 feet above the *Diploschiza melleni* Stephenson zone which Stephenson (1935, 1937) says should pass through the Corsicana marl of the Navarro group in Texas. Its other diagnostic associates are *Exogyra costata* Say, *Crenella serica* Conrad, and a minute unnamed brachiopod.

**Lituola erecta** sp. nov.

Fig. 2; Fig. 4, middle row.

The test is long, crosier-shaped, and slightly compressed in the early close-coiled portion. The later portion is very abruptly uncoiled and erect in the adult forms. The numerous labyrinthic chambers have very irregular, rough interiors, the number in the coil varying in the microspheric and megalospheric forms and in the young and adult stages. The sutures are indistinct and but slightly depressed. The wall is arenaceous, well cemented, and rough on the exterior. The aperture is terminal and multiple or cribrate, and occupies all the apertural face.

Maximum length 9 mm.; width of coil 2.5 mm.; thickness 2 mm.

Holotype, from the outcrops behind the J. W. Martin home in the SE. 1/4 sec. 31, T. 19 N., R. 14 E., Oktibbeha County, Mississippi, is in the collections of the Mississippi Geological Survey.

*L. erecta* is found in abundance in the numerous outcrops of the thin Clayton formation in Oktibbeha County. In the present study collections were taken behind the J. W. Martin home and half a mile south of the Poor House road in the E. 1/2 sec. 28, T. 18 N., R. 14 E. It is very abundant in Clay County 3 miles north of Pheba in the SW. 1/4 sec. 4, T. 20 N., R. 13 E.,

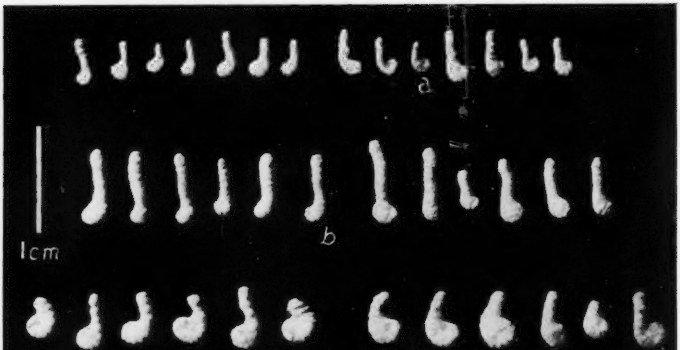


Fig. 4. Top row, *Lituola erecta distincta;* a, holotype of new subspecies. Middle row, *Lituola erecta;* b, holotype of species. Bottom row, *Lituola taylorensis* Cushman and Waters.

and is known from the Clayton of Noxubee County. Throughout Clay, Oktibbeha, and Noxubee counties the Clayton formation is composed largely of small, marine, invertebrate fossils among which *Ostrea pulaskensis* Harris and *L. erecta* are unusually abundant. *Turritella mortoni* Conrad, abundant in the lowest Clayton beds in northern Mississippi, is known in this region from only a few internal molds.

**Lituola erecta distincta** subsp. nov.

Fig. 3; Fig. 4, top row.

The subspecies differs from *L. erecta* in the more evolute coiling, in the more depressed sutures, and in size, having a maximum length of 5 mm., a width of 2.5 mm., and a thickness of 1 mm. The interiors of the chambers are smooth and the sutures are distinct.

*L. erecta* subsp. *distincta* has been collected in Noxubee County from a road cut on the south valley wall of Lynn Creek, sec. 22, T. 16 N., R. 15 E. The collection was made March 6, 1936, by E. H. Rainwater and F. F. Mellen from a 5 by 40 inch sandy and calcareous lens in the Porters Creek clay 5 or 10 feet above the Clayton formation. This form is very abundant in the lens and in the conchoidal clay above and below. Several imperfect specimens were found in Clay County, 3 miles north of Pheba in the SW. 1/4 sec. 4, T. 20 N., R. 13 E., near the base of the Porters Creek formation. Field work has not yet disclosed the presence of this form in Oktibbeha County. Mrs. Helen Jeanne Plummer sent us two specimens of a form from the N. 1/2 NW. 1/4 sec. 10, T. 12 S., R. 24 W., north of Hope, Arkansas, of basal Midway age which is referable to this variety.

ACKNOWLEDGEMENTS

We are indebted to Mrs. Plummer for sending us typical specimens of *L. taylorensis* Cushman and Waters and for revision of our manuscript. Dr. M. L. Thompson who is very familiar with the region under discussion and with the fauna of the Midway very obligingly criticized this manuscript. We also wish to thank Dr. W. C. Morse, Director of the Mississippi Geological Survey, University, Mississippi, who granted use of the Survey laboratory facilities, and gave permission for the publication of this paper.

## REFERENCES

CUSHMAN, J. A. AND J. A. WATERS. 1929—Contributions from the Cushman laboratory for foraminiferal research. **5**(3):66.

GUEST, H. G. 1935—The Ripley formation in east-central Mississippi and west-central Alabama. Thesis for the doctorate, the State University of Iowa.

STEPHENSON, L. W. 1914—Cretaceous deposits of the eastern Gulf region, and species of *Exogyra* from the eastern Gulf region and the Carolinas. U. S. Geol. Survey Prof. Paper **81**.

———1917—Tongue, a new stratigraphic term, with illustrations from the Mississippi Cretaceous. Jour. Washington Acad. Sci. **7**:243-250.

———1934—The genus *Diploschiza* from the Upper Cretaceous of Alabama and Texas. Jour. Paleontology **8**(3):273-280, pl. 38.

———1935—Further notes on the Cretaceous pelecepod genus *Diploschiza*. Jour. Paleontology **9**(7):588-592, pl. 70.

——— AND W. H. MONROE. 1937—Prairie Bluff chalk and Owl Creek formation of eastern Gulf region. Bull. Am. Assoc. Petroleum Geologists **21**(6):806-809.

# Book Reviews

WHAT SNAKE IS THAT? A FIELD GUIDE TO THE SNAKES OF THE UNITED STATES EAST OF THE ROCKY MOUNTAINS, By Roger Conant and William Bridges. New York: D. Appleton-Century Company, 1939. x + 163, frontispiece, pls. A-C & 1-32. $2.00.

It is my conviction that a conscientious reviewer should be critical; but I am now confronted with a most carefully prepared little book, and I fear that in adhering to my policy I may succeed in proving only that my own knowledge of snakes is less detailed than that possessed by the authors of the book. Many of us have admitted the crying need for a handy field book which would enable beginners to identify snakes, but we have quailed at the amount of labor involved in the preparation of such a guidebook. Conant and Bridges have stepped into the welter of publications stemming from the work of the late Frank N. Blanchard, and have incorporated all recent taxonomic and nomenclatorial changes into a book which has the rare distinction of being absolutely up-to-date at the moment of publication.

The introductory section of the book consists of nineteen pages, arranged as follows: eight pages devoted to the ways of serpents, eight to snake bite treatments, and three to the definition of a very limited number of necessary terms. In view of the commendable brevity of this last section its title, "Snake Dictionary," appears somewhat contradictory. Although recognizing the exigencies of space requirements, I cannot fail to regret the absence of any reference whatsoever to the sense organs of snakes. Admittedly, these are adequately treated in other popular snake books of greater scope, but the readers to whom the present volume is addressed do not possess six-foot shelves on herpetology. The function of the tongue, the rôle of scent in trailing food or prospective mates, the amazing temperature sensitivity of the facial pit of crotalid snakes, and the virtual deafness of most serpents could have been treated briefly in two additional pages. And there is a blank space on page eight which might have carried a stinging rebuke to the proponents of "vermin" campaigns!

Pages 20 to 26 are devoted to an "Identification Key" covering the 132 species and subspecies occurring east of the Rocky Mountains. The reader is referred to a frontispiece map on which the cismontane region is plainly divided into six numbered "areas," comprised of groups of entire states; then, in the key the forms of each area are found grouped under four headings, which are combinations of only two simple characters—scales keeled or smooth, and anal plate single or divided; final identification is accomplished by reference to the plates which follow. How usable this type of key will prove to be no professional herpetologist can foretell. Those of us who write keys presumably know our material too well to have use for them, and it is a constant surprise to find students going astray at points which appear perfectly plain to us. Many persons who would be frightened by a long key of the conventional type will make an attempt to use this one, for it possesses the virtue of conciseness and it caters to a natural preference for identification from pictures instead of scale counts. The only mistake noted is the omission of the Horn, or Mud Snakes *(Farancia abacura abacura* and *F. a. reinwardtii)* under areas 3 and 4. Most beginners will appreciate the demarcation of the six basic areas along state boundaries, although biologists prefer physiographic divisions which correspond more closely to actual distributional facts. Even on the basis of state boundaries I should argue for the inclusion of West Virginia in Area 1 with Pennsylvania and New England, since southern elements are almost lacking in the West Virginia snake fauna, and for the allocation of Maryland, Delaware, and New Jersey, which do have such constituents, to the more southern Area 2.

The key is followed by 35 plates, each of which displays several species diagram-

matically; head profiles, details of scutellation, pattern fragments, dorsal or ventral views of entire snakes, and two types of flattened-skin drawings are used as required. The drawings made from flattened skins, split either along the median line of the belly, or at one side, exhibit the complete patterns, but these figures lack a serpentine appearance; in fact, those split along the side of the belly bear a marked resemblance to gymnotid eels. In their introduction the authors state "The illustrations, prepared with infinite pains by Edmond Malnate, represent without a doubt the finest collection of North American snake drawings in existence." With this statement I am not prepared to agree. I think that Mr. Malnate is a capable artist and that he faithfully executed the task which he was given; namely, the preparation of a series of conventionalized drawings for use in connection with the key. The series is the most extensive set of drawings *of this type* with which I am acquainted, but I maintain that it is unfair to the illustrator to suggest comparison of these schematic drawings with water colors by Deckert, or steel engravings by Richards.

Pages 27 to 155 are devoted to discussions of the various forms, each including a brief statement of the range, size and appearance, in small type, and a general section, in larger type, dealing with habits, habitat, feeding and reproduction. The authors are to be complimented upon their foresight in including both the Glass Lizard and the Worm Lizard, since many persons mistake these legless creatures for snakes, and naturally expect to find them in a snake book. The forms recognized reflect the current views of taxonomists, except that the Texas Indigo Snake, *Drymarchon corais melanurus* is combined with *Drymarchon corais couperi*, which ranges from South Carolina to Florida. These snakes are not easy to separate on structural characters, but the wide gap between their ranges justifies continuance of their subspecific separation pending a thorough study.

There are a few minor errors in the book. For example, on page 3 the statement is made that a Timber Rattlesnake is not likely to be encountered when one has a picnic cloth spread out in a meadow. Unfortunately, such distressing encounters occasionally take place in western Pennsylvania when summer drought on mountain ridges forces rattlesnakes to descend to the valleys for water. On page 5 the period of incubation of snake eggs is stated to be from "a few days to several weeks"; the eggs of some snakes require more than two months for incubation. On page 11 appears the dangerous statement that "a slight delay seldom is harmful" in initiating snake bite treatment; immediate incision after a serious bite is of great importance, since the first rush of blood sometimes washes pure venom out of the wound. It is better for a few persons to incise harmless snake bites unnecessarily than for treatment of a Diamondback bite to be postponed.

The index is adequate, typographical errors are few, and the book is of a convenient size and well bound. Some plates would benefit in appearance from wider margins, but none are damaged by close trimming.—M. Graham Netting.

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Turtles of the United States and Canada. By Clifford H. Pope. New York: Alfred A. Knopf, 1939. xviii + 344 + v, 99 photographs. $3.75.

"I firmly believe that the average individual is just as interested in fundamentals of science as are the scientists themselves, but it is patent that these basic facts must be presented in familiar terms as free as possible from technical language." This quotation from his preface may be taken as Clifford Popes credo; one which does him great credit and which results in the writing of excellent books, of interest to laymen and professional herpetologists alike. All too many popular books on animals are written by persons who lack the thorough understanding so necessary to the presentation of the fundamentals of a particular branch of biology. Much of the scientist's scorn of "popular" writing is directly traceable to the shallowness of such books and to their numerous inaccuracies. A herpetologist of Pope's experience could dash off a passable reptile

book with relatively little effort, but he invariably chooses the more laborious and more scientific method of digesting all pertinent literature before he begins to write. This is honest craftsmanship; it resulted in "Snakes Alive" being an entrancing and accurate book; it has led also the publication of the first book devoted exclusively to American turtles. This second volume is as carefully written as its predecessor; in addition, it displays a vast improvement in the author's ability it present animals as distinct personalities without any distracting personification. "Snakes Alive" was a thoroughly good book; this book is even better. In fact, the introductory portion is such delightful reading that all herpetologists will be led to hope that Pope will devote his very decided talents in popular writing to the production of other herpetological books. Everyone of us who has had to cope with the widespread interest in the sex life of turtles will be eternally grateful that matters of courtship and copulation are discussed with utter frankness.

Both "pro" herpetologists, as Pope calls us, and turtle fanciers should be equally grateful to Mark Mooney, Jr. whose excellent photographs do full justice to many beautiful turtles. His angle shots have a freshness, as well as an illustrative value, sadly lacking in many reptile pictures. No recent reptile book contains illustrations so uniform in their excellence.

Not all taxonomists will concur with some of the changes in nomenclature introduced in this book, but all will agree that no other American herpetological group has been in such a slough of nomenclatorial desuetude. Pope has had the courage to decide some problems; he has availed himself of the advice of various students of turtle classification, and he has swept away the fog of taxonomic uncertainly which has swirled around many of our turtles. In general, he has adopted an advanced rather than a conservative position, and has relegated to subspecies, on theoretical or geographical grounds, certain species in which intergradation has yet to be proved. Some of these changes are supported by unpublished studies to which he has had access; others may be substantiated when adequate studies are made; some may prove to be incorrect. For example, this reviewer questions the use of *Chelydra serpentina serpentina*, for Pope neither recognizes *osceola*, nor offers any evidence that *C. rossignonii rossignonii* is conspecific; but he gladly seconds the well merited praise of Deraniyagala's studies of marine turtles.

Stejneger and Barbour[1] recognize 73 species and subspecies of turtles as occurring in the United States, Canada and Lower California. According to the publisher's blurb on the jacket Pope recognizes 63 forms in the United States and Canada; actually he includes only 62! He does not recognize, or omits as extra limital, the following 11 forms which are to be found in the Check List (it should be mentioned that both works were in press at the same time):

- *Kinosternon baurii palmarum* Stejneger
- *Chelydra osceola* Stejneger
- *Graptemys pseudogeographica kohnii* (Baur)
- *Pseudemys concinna hoyi* (Agassiz)
- *Pseudemys ornata nebulosa* (Van Denburgh)
- *Pseudemys troostii elegans* (Wied)
- *Chelonia agassizii* Bocourt
- *Eretmochelys imbricata* (Linné)
- *Dermochelys schlegelii* (Garman)
- *Amyda agassizii* (Baur)
- *Amyda spinifera aspera* (Agassiz)

He follows Malcolm Smith in considering the American soft-shells congeneric with Old World *Trionyx*. In addition, he transfers *Caretta olivacea* to *Lepidochelys* and *Caretta kempii* to *Colpochelys*. Eleven full species in the Check List become trinomials in Pope's list; two Check List trinomials are considered full species by Pope; and six subspecies are referred to different species in the two books.

Many of the English names used are exceedingly apt, but there are some evident inconsistencies. For example, *Pseudemys rubriventris bangsi* is called the Plymouth

1 Check List of North American Amphibians and Reptiles, 4th ed., 1939.

Turtle, *P. r. rubriventris*, the Red-bellied Turtle, and *P. nelsoni*, the Florida Red-bellied Turtle. Actually *P. r. bangsi* has the reddest belly of the three forms, a fact which could not be inferred from the name "Plymouth Turtle"; Northern, or Massachusetts, Red-bellied Turtle would be more expressive of the close relationship. "Cooter" is such a widely used name for various forms of *Pseudemys* that I think its use in certain English names might have been desirable.

Extremely few factual errors, none of them serious, occur. The following examples are evidence of my inability to find any mistakes of importance. Contrary to the statement on page 82, Snapping Turtles do become tame with patient handling; I have seen one which was a children's pet; and another large docile individual, in the hands of a turtle fancier, subsisted on wieners! *Clemmys insculpta* does have a market value; thousands were sold in Pennsylvania markets before the passage of the Terrapin Act in 1917. The key to species of *Clemmys* on page 85 is not wholly accurate; western specimens of *insculpta* often have yellow rather than "salmon red" skin and many *muhlenbergii* have a yellow rather than an orange temporal blotch. The distribution of the Eastern and Central Painted Turtles in Pennsylvania is incorrectly defined. All Susquehanna Drainage specimens are intermediate between *picta* and *marginata*, over three hundred Carnegie Museum specimens from this river system having been independently identified as intermediates by Atkinson, Hartweg, and the writer without disagreement over a single specimen. In Pennsylvania, typical *picta* is restricted to the Delaware Drainage and typical *marginata* to the Lake and Ohio drainages. On page 222 the statement is made that *Pseudemys scripta scripta* sheds its epidermal shields, but the figured specimens (figs. 77 & 78) show distinct growth rings.

Probably each herpetologist has stored in his mind or notebooks certain observations about turtles which would have found place in this volume if they had been made available to the author, but it is obvious that few published data have escaped his careful scrutiny. Unfortunately, a recent paper by Richmond and Goin[2] has gone unnoticed. This paper contains a valuable comparison of the hatchlings of *Pseudemys rubriventris rubriventris* and *Pseudemys nelsoni;* the variations in plastral markings and coloration of the former are described; and the egg-laying of adult females in New Kent County, Virginia, at various dates in May is reported. The importance of light as a factor in the breeding cycles of turtles is deserving of greater emphasis and merits treatment in the introductory section of the book, rather than in a casual fashion under the discussion of *Pseudemys scripta troostii.*

Scientists are accustomed to encountering diphthongs in technical publications, although even in these there is a growing and laudable tendency to dispense with such printers' hazards; for example, Stejneger and Barbour[3] do not use diphthongs even in the endings of family names. It is a distinct shock, therefore, to find Testudinidæ, gaigeæ, vertebræ, æon, fæces, larvæ, cloacæ, algæ, and æstivation in a popular book. British spellings, although they do not impede reading to any extent, are even more out of place in an American volume by an American author; examples are millimetre (a spelling now incorrect even in Great Britain),[4] centre, mould, favourite, colour, and labourer. Typographical errors are amazingly few; page 126 appears to hold the record for the volume with two—"comon" and "verticle."

Most of the 800 odd papers on American turtles were studied in the preparation of this book; some one hundred and sixty of the most important are listed in the bibliography. In this bibliography the author has wisely used complete citations and avoided the conventional abbreviations which might confuse "amateur" readers. A useful list of the species treated, with chapter and page references follows the bibliography. The index is accurate and reasonably complete; perhaps subject indexing of the discussions of individual species would have lengthened it unduly. Numerous valuable suggestions for investigative studies of turtles are scattered throughout the text. These

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2 Annals Carn. Mus. **27**:301-310, 1938.

3 *Supra cit.*

4 Fowler, H. W. A Dictionary of Modern English Usage. London: 1927.

might well have been summarized in a separate appendix for the convenience of readers who may have opportunity for such studies.

It is to be hoped that the advance copy of the volume which was sent to this reviewer is not typical of the entire edition. It is poorly folded and cut, and the practice of "bleeding" the illustrations has resulted, as usual, in some amputations.

—M. Graham Netting.

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Bats. By Glover Morrill Allen. Harvard University Press, Cambridge, Mass., 1939. Price $4.00. Pages i to x, 1 to 368. Frontispiece of a Little Brown Bat in flight making a turn, one of the most unique and perfect mammal photographs which the reviewer has ever seen, and 57 other illustrations, many of them full page.

The author, from his official position in the Museum of Comparative Zoology, Harvard University, from his published writings and from an almost world wide experience in collecting bats, is well qualified to write on the subject matter of this book. It contains a vast fund of knowledge about bats and represents an amazing piece of bibliographic work on the part of the author. He writes in a very entertaining manner and makes a technical subject as non-technical as is possible. Most of the book will be perfectly intelligible to the layman, but the reviewer feels that one who has never studied nor collected bats will not gain a true appreciation of the subject in all its details.

The twenty-one chapters include such subjects as: Bats in Folklore, Strange Uses of Bats by Men, Bats as Pets, as Food, Where they hide, What they live by, Their Teeth and Their Meaning, Probable Origin of Bats and the Great Antiquity of the Group, The Geographic Distribution of Bats, Their Social Habits, Breeding Habits, Migrations, Hibernation, Enemies, a long chapter on the parasites of bats, Bats in Relation to Diseases of Man, of little importance, and in Relation to Diseases of Animals, which apparently is of considerable practical importance to owners of live stock in tropical America.

One of the most interesting chapters is "Bat Flowers," setting forth very recent work, particularly that of Porsch in 1932. The cross fertilization of flowers by insects has long been known; now it is recently shown that cross fertilization is effected in the case of certain flowers only by the nightly visits of bats which seek them out for their contained nectar and pollen. Doctor Allen's treatment of this subject, while brief, is as entertaining as the work done by Darwin on the cross fertilization of orchids by means of insects.

The chapter on What Bats Live By is particularly interesting. Their food ranges all the way from fruits and flowers to smaller vertebrates attacked by the members of the Megadermids in the Old World and by certain members of the New World such as the larger Spear-Nosed Bats. Naturally the most interesting food habit of any bat is that of the celebrated Vampire of Central and South America, which is a true ectoparasite and lives by lapping up the blood of animals whose epidermis it has scraped off by means of its highly specialized teeth. Another food of certain bats is small fishes, which they grasp from the water by means of their enormously developed hindfeet. The larger of these fish-eating bats had for some time been known to have this habit, but it remained until 1928 for Miller to suggest that a recently smaller and unrelated one ate fish, and until 1932 for Burt to prove that it did. Still another food habit is cannibalistic; certain larger bats prey upon smaller ones.

One of the most serious chapters in the book is the Relation of Bats to Diseases. It has recently been shown that the blood-eating vampires transmit hydrophobia to domestic animals and undoubtedly to man, if he is unfortunate enough to be bitten by an infected bat. The poor vampires are perhaps entirely innocent, and probably not until man brought to the New World live stock infected with rabies did they become carriers of the disease. Diseases of lesser import are also transmitted by these ectoparasitic bats. His chapter on the Parasites of Bats is especially interesting, and should convince any one that the "bugs" on bats are confined to bats and never attack men.

In the two related chapters, An Ancient Lineage and The Geographic Distribution of Bats, the reader will find much to entertain him. As the author says, bats were "perfectly good" bats as far back as tertiary times, some sixty million years ago. They probably had their origin from an arboreal insect-eating animal, perhaps something related to the modern tree-shrew.

Perhaps one of the most entertaining chapters is entitled The Caves of Yporanga, and shows how enthusiastic one may get collecting bats and how one may spend days and hours in their quest and yet come back empty handed.

The author's concluding sentence, based upon their known social habits and the association of unlike species in fossil deposits as well as modern caves is worthy of thought, "Indeed bats have much to teach us about good citizenship."

The only omitted subject the reviewer feels is one on the "Histology of Bats." Perhaps this has not been fully written yet, although the author makes references to specialized sense organs. The reviewer once had the notion that the curious nose pieces of bats had something to do with their keen sense of direction in the dark. He sectioned some nose-leaves, but all he found with the ordinary stains were sebaceous glands. Other work prevented further research.

The book is well made, free from typographical errors, handsomely illustrated. The author is to be congratulated on such a complete and entertaining piece of zoological literature.

The reviewer hopes that the author will not have made the subject of bats and bat collecting too popular, and thus do anything to lead to the extermination of any species of this interesting group. It is possible that when it is known that vampires are responsible for the transmission of disease, steps might be taken to wipe them out. To the average person a bat is only a bat, and no discrimination might be shown against sparing the true vampires. The reviewer often wonders what is the effect on the homelife of bats by the exploitation of caverns for visitors and the installation of electric lights.

A bibliography and a well made index close the work. Two omissions in the bibliography strike the reviewer, one is Darwin's mention of being present when a vampire was caught on one of his horses on the night of about April 10, 1832 (Voyage of Beagle); the other Dobson's classic Catalogue of the Chiroptera, 1878.

—Marcus Ward Lyon, Jr.

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Prehistoric Life. By Percy E. Raymond. Harvard University Press. Cambridge, Mass. 1939. ix + 324 pp., 156 figs. $5.00.

This book is an outgrowth of and, apparently, a textbook for a beginning course in paleontology which Professor Raymond has given at Harvard during the past eighteen years. Informal and definitely personal in style, it sets out to inform students concerning the facts, theories and problems of paleontology which most interest the author. It also is an effort to offset narrow specialization, since Professor Raymond believes that "the broader the background, the better the specialist."

His success in this effort must be judged subjectively; no objective standards exist. To this reviewer, a book which devotes 63 pages to the invertebrate phyla, 199 to chordates and 10 to plants cannot present a really comprehensive background; it is bound to neglect much important background material of paleobotany and invertebrate paleozoology and overemphasize (relatively, at least) the single phylum of chordates in which only one main group are at all common as fossils. Even if we grant that the anatomy, phylogeny and ecology of fossil vertebrates is more varied and more attractive in popular terms than that of brachiopods or gastropods, the odds are not so overwhelmingly with the vertebrates. Moreover, studies of phylogeny and ecologic biology in a few invertebrate groups indicate that they will afford a wealth of "back-

ground" information once paleontologists seek it out. Professor Raymond's own studies of trilobites, which are scantily represented in an 8-page chapter called "Petrified Butterflies," amply support this claim. And does not the over-emphasis on vertebrates which characterizes most popular books and several texts discourage young paleontologists from studying the biology of invertebrates as that of vertebrates has been studied?

One also must question the value of Professor Raymond's chapter on "Pre-Cambrian Life." This undoubtedly is a field in which there has been much uncritical work and hypothetical taxonomy: yet some of the criticisms which seek to discard most supposed pre-Cambrian fossils as results of crystallization, concretions, ripple marks and mud-cracks have been quite as uncritical. With these uncritical criticisms we must place Professor Raymond's own statement that "for the past twenty years everyone has been finding calcareous algae"—especially when his review seems to consider no papers on calcareous algae published within the past 18 years. As for the objection that paleontologists cannot prove their determinations of pre-Cambrian phyla: what paleontologist can "prove" the phyletic determination of stromatoporoids and the small tabulate "corals?" Are we therefore to eject both groups from the fossils?

In short, while skepticism is needed in dealing with pre-Cambrian fossils, as with every other scientific subject, uncritical skepticism may easily do harm. The revulsion from the fucoid theory shows that clearly; beginning as a justified protest against the promiscuous naming of tracks and burrows as plants, it has progressed to such a stage that most paleontologists and stratigraphers ignore them entirely, thereby robbing us of a vital source of information concerning the habits and ecology of ancient littoral and near-littoral animals. With them, as with the calcareous and early carbonaceous algae, paleontology seems most likely to achieve broad backgrounds if it combines skepticism with a willingness to work as if certain hypotheses are true, going backward, if need be, to get results.

These criticisms are themselves uncritical in that they ignore the many good features of the book, especially in chapters dealing with arachnids and vertebrates. Best of these good features is sprightly readability. Students in Paleontology I at Harvard may get too much about some groups and too little about others, but what they do get will not be dull.—C. L. FENTON.

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ALGAL BARRIER REEFS IN THE LOWER OZARKIAN OF NEW YORK. By Winifred Goldring. N. Y. State Museum Bulletin 315. Albany. Pp. 1-75, 22 figs.

Forty-two pages of this paper are devoted to descriptions of the three species of *Cryptozoon* found in the lower Ozarkian rocks of New York, of the barrier reefs which they built, and the evidence on which Dr. Goldring reaffirms the conclusion that *Cryptozoon* is a plant. There is a brief discussion of the alteration of coralline algal deposits, a chapter on the importance of algae as builders of reefs and bioherms, and an excellent bibliography. As the most detailed, as well as the most recent, study of Cryptozoon, this paper merits the attention of paleo-botanists and stratigraphers.

—C. L. FENTON.

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